HCA

WHAV

ENGINEERING REPORT

****

May, 1943

by-
John W. Severinghaus
Chief Engineer

WHAV - ENGINEERS REPORT May, 1943

Preface

During the school year 1942-3, a campus radio station was constructed and put into operation at Haverford College, and later at Bryn Mawr College. For the purpose of enlightening future members of the engineering staff of WHAV, for a permanent record of the technical operation and construction of the station, and as a report to the members of the Physics Dep't at Haverford who have made it possible for WHAV to become a reality, both from the technical and financial standpoint, this paper has been written by the chief engineer.

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Conception of WHAV (formerly W3HAV)

"Is that you playing those corny South American records, Clark?"

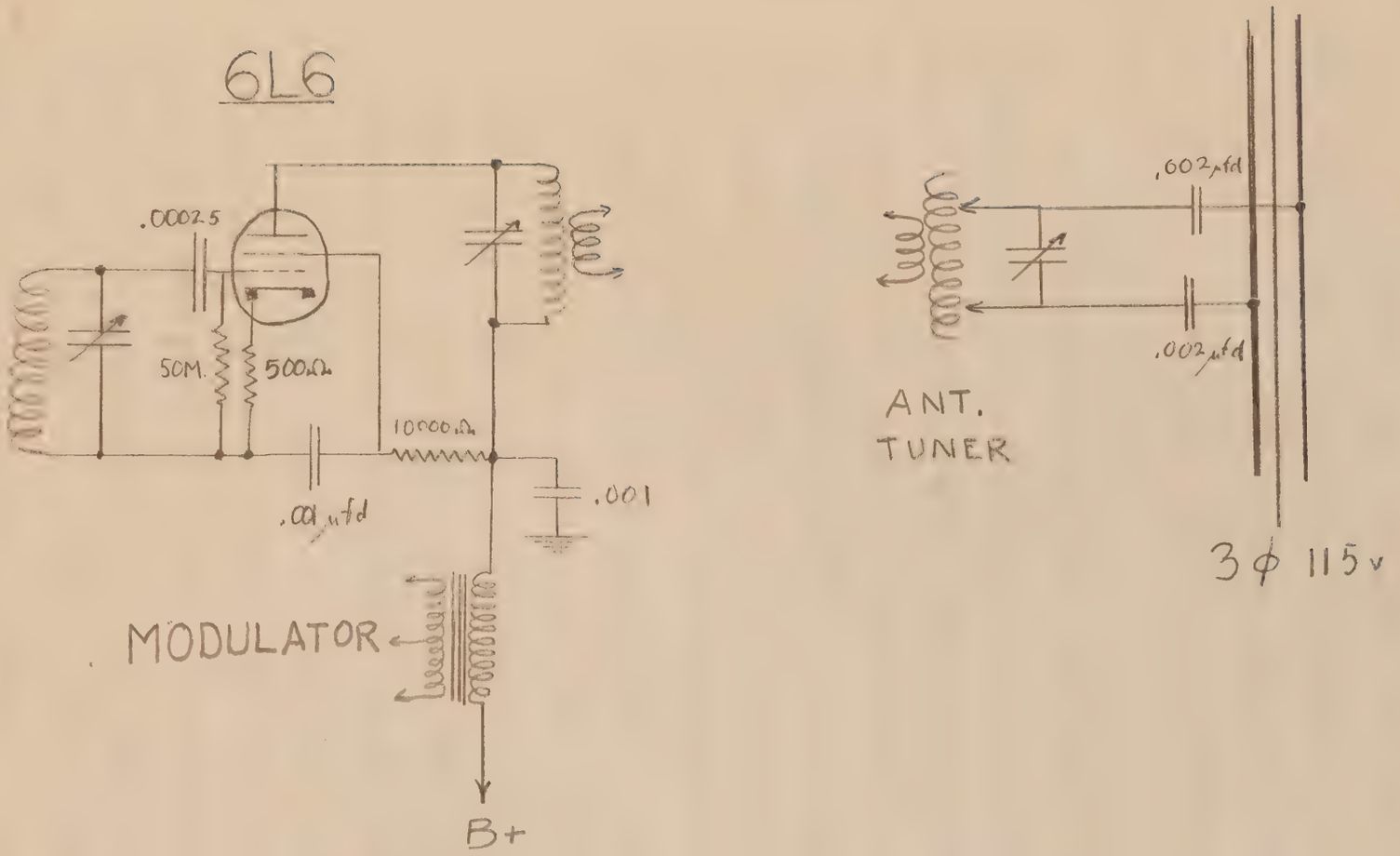
"That's right - why?"

"They're coming in on my radio at the other end of the hall - you tell me why."

"Hey, Gray, did you get that? He says he can hear this darn phono-oscillator down at the other end of the hall!"

With a slightly larger antenna, it was found that all of Founders could recieve the signals. With Ken Foreman's help, a microphone was added to the "transmitter" and comments to the music which had formerly been played only for Clark's and Gray's pleasure. Founders enjoyed listening to good music when none was to be found on the radio, which was and still is most of the time. When the original oscillator ceased to oscillate, and couldn't be fixed, a collection was taken up for a new one. About this time Clark heard of the Intercollegiate Broadcasting ~~Service~~ System, known as the IBS. He read of other colleges broadcasting all over the campus, and dreams were created in no time. When it was learned that Swarthmore had one, we knew that Haverford could not be out-done.

In May of 1942 plans began humming for the transmitter and all possible associated equipment. After digging sufficiently deep in the physics laboratory, a good deal of old



WHAV

ORIGINAL TRANSMITTER
(NEVER USED)

Fig. 1

equipment was unearthed which had belonged to the predecessor of the new radio club. It was also learned that an endowment of some $1500 belonged to the radio club and that the income from it was obtainable each year. In 1940 the radio club had wisely spent this money on an RME - 69 reciever, a very excellent and servicable communications reciever. The 1941 sum had not been used, and with the 1942 amount, was turned over to the radio club.

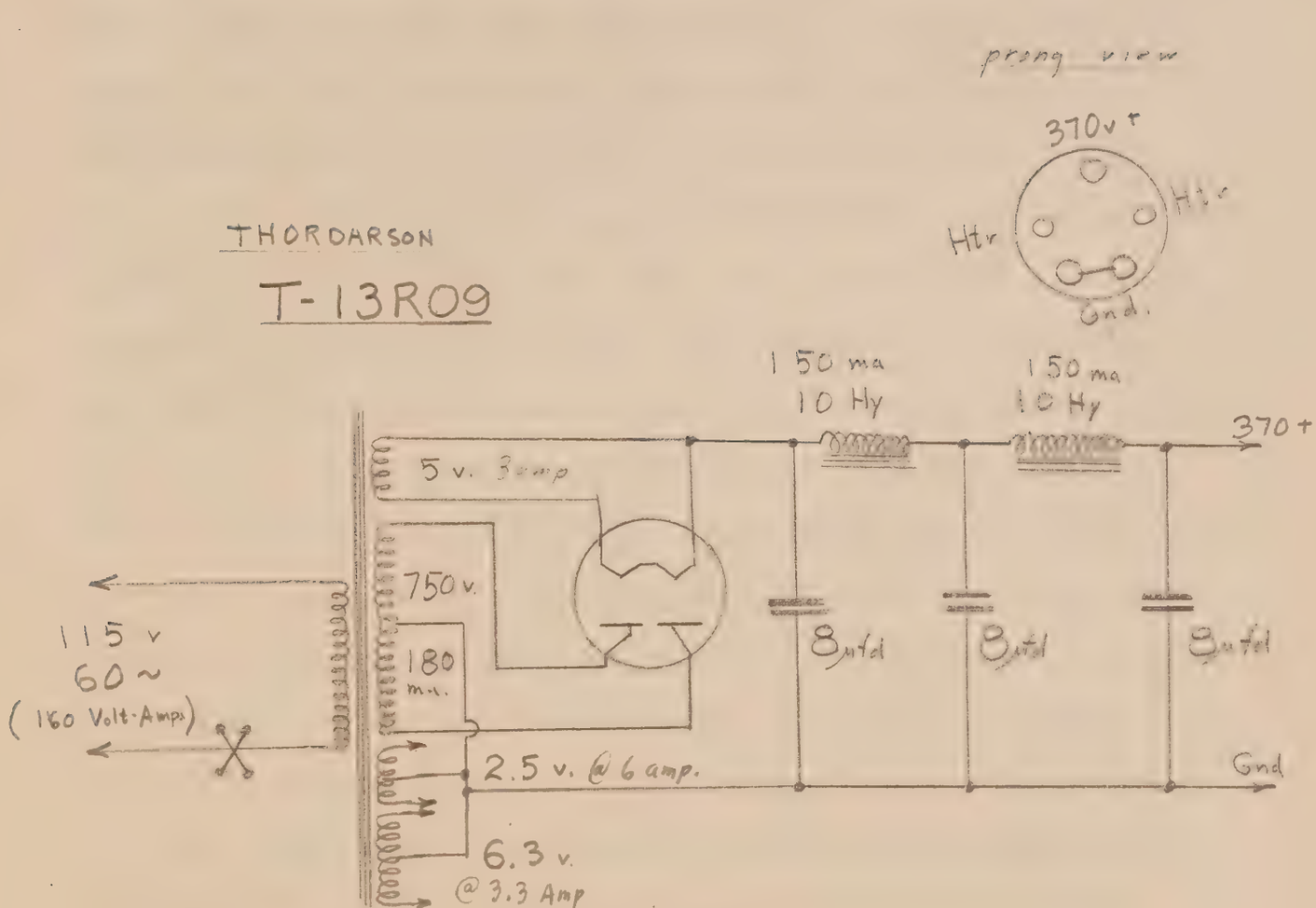
It was decided that over the summer Thomas would build a preamplifier and mixer; Gray would build a power supply, since he had all the parts; Severinghaus would build the transmitter. The original preamplifier is still in service, with slight additions, and will be described in detail later. Gray went to the Tetons to study geology, and the power supply waited till fall. Since the transmitter built by Severinghaus has been replaced, the original will be described here.

Figure 1 is the diagram of this transmitter. It is a tuned plate-tuned grid oscillator employing a 6L6. The circuit is conventional, and was lifted in part from the ARRL Handbook. Its description may be found on page 210 of the 1942 edition, with the change from crystal to tuned circuit in the grid. The fact that it would be a plate modulated oscillator, and thus have frequency as well as amplitude modulation did not seem apparent to the planner. This apparatus was never used, however, because when September came, it was learned that Thomas and Mr. Benham had built on breadboard a crystal controlled 6L6 with an antenna tuner.

Fig. 2

WHAV

TRANSMITTER POWER SUPPLY



II. Assembly in September, 1942

This breadboard layout with the antenna tuner was the transmitter used for several weeks after the opening in early November. But when school opened in September no one knew where the studios were to be. Possibilities of 1) Founders Hall in one of the unoccupied rooms in the East wing. 2) One of the attics in Lloyd Hall 3) the third floor of the Haverford Union, had been considered. Mr. Wills gave his consent to the latter, and WHAV began to move in. The small closet which is now the engineer's booth seemed very small. The shelf and tables were added, and that became the transmitting room as well as the control room. When first seen, the room had only one 110volt outlet. Extensive wiring was necessary, power wire being carried to the booth calculated for 15amps maximum. One phonograph turntable had been purchased at Archer and Evinger in TerreHaute, Ind. That is the fine Garrard instrument still at the engineer's RIGHT. A Shure pickup with high impedance crystal cartridge was installed with it. For the second turntable, John Clark lent his, and it has not been returned at the present time. An Astatic transcription pickup was purchased at Herbach and Rademan in Philadelphia to go with it.

The power supply for the transmitter was planned with considerable leeway. The entire unit will handle 150ma. at 350 volts, condenser input. Figure 2 is the diagram. At the present writing the transformer has been placed in

the modulator, and that of the latter placed in the transmitter, since the transmitter draws only 60 ma and the modulator about 110ma. Higher voltage was desirable in the modulator also since it was found to be impossible to modulate 100% with the original arrangement. The modulator transformer is rated at 700 volts C.T. , 70ma.

Before we could begin broadcasting the means for feeding the RF signal to the dormitories had to be considered. We had fully expected to put the transmitter in the basement of Lloyd under 5th entry, and later add another transmitter in the basement of Barclay. Founders, on the same circuit as Lloyd would receive the same signal. Taking a hopeful step, the engineers put the transmitter in the Union and ran an RF feeder to Lloyd where it was tapped into the power wiring. This proved sufficient to cover even Founders. The method of covering Barclay will be discussed later, but was originally done by feeding into the power circuit of the Union and connecting the latter to that of Barclay thru .002ufd. condensors.

Opening day was rather hectic for the engineers. The transmitter itself balked and refused to oscillate. Mr. Benham was pressed into service at about four in the afternoon and found the difficulty in about five minutes. The bottom end of the oscillator plate tank was not grounded thru a condenser, consequently a large part of the RF was being developed thru the isolating resistor of 10000ohms. Opening was scheduled for 8:00 pm and the ~~Founders~~ Barclay line was not satisfactorily fixed until ten minutes till eight,

Despite the haste, opening night went off quite well. The only trouble was a poorly shielded mike cable which picked up RF from the antenna, detected it in the 6F5 of the preamp., causing low frequency motorboating. The cause was found during the first speech and that mike was not used after that. Reception was far from ideal, however, and the facility of movement and control was limited in the studio. The beginning of broadcasting marks not the end but more the beginning of technical development, and it is the improvement and modification that will be the subject of the next section of the paper.

III. Problems and Solutions

From November 10, our opening date, to date, most of the time spent and work done on WHAV has been to cure some ill. Not until we run into trouble do we seek to prevent its recurrence. Or when one of the engineers sees something that could be improved, he is welcome to try to improve it. The transmitter, being the heart of the station, rates the first description.

Figure 3 shows the transmitter as of Jan. 1, 1943. It is very much the same at the present writing. The first notable change from the crystal controlled 6L6 is the 6C5 oscillator tube, which was added while in the experimental stage, during October. There are two reasons for using a

TABLE I

Harmonics of WHAV received on the RME

no.	freq.	comment	no	freq.	comment
1	.580	fundamental	p	19.55	first parasitic noted
2	1.160	bad buzz	34	19.95	
3	1.760	worse buzz	p	20.2	loud spkr vol
4	2.340	faint	?	20.4	
5	2.89	loud, quiet(no buzz)	35?	20.7	
6	3.42		?	21.0	very clear
7	3.98		36?	21.3	faint
8	4.54		?	21.5	clear
9	5.10		?	21.8	faint
10	5.66		?	22.1	loud
11	6.27		?	22.4	faint
12	6.85		?	22.7	very loud
13	7.41		?	23.1	clear
14	7.95		?	23.2	clear
15	8.52		?	23.6	loudspeaker vol
16	9.10		?	24.2	faint
17	9.66		?	24.7	clear
18	10.24		?	24.9	fair
19	10.82		?	25.2	clear
20	11.42		?	25.5	v. faint
21	12.00		?	25.8	clear
22	12.6	use of phones	?	26.0	clear
23	13.2	begins here	?	26.3	very loud *
24	13.7		?	27.0	quite loud
25	14.3		?	27.2	clear, carrier only
26	14.9		?	27.5	clear
27	15.5	indiscriminate		27.7	clear, " "
28	16.1			28.2	clear
29	16.7			28.3	
30	17.3			28.7	distorted loud
31	18.0			28.9	un modulated
32	18.6			29.3	faint
33	19.3	strong		29.5	unmodulated
				29.8	modulated
				30.1	unmodulated
				30.5	faint
				30.7	unmodulated
				31.0	
				31.8	loud, end of dial

separate oscillator stage. One is to prevent overheating of the crystal due to the alternating component of the grid current. In the 6L6 this alternating component is about 18ma., which is calculated from the operating conditions. The assumption is made that the D.C. grid current is 15% of the total D.C. space current. The A.C. grid current is twice the D.C. With 60 ma. plate current, we have 9 ma. (space) D.C. grid current and therefore 18 ma. A.C. The heating was not sufficient to damage the crystal, but since WHAV does not operate the crystal in a temperature controlled oven, the frequency drifts with the temperature, causing slight misallignment of the transmitter. This is quite true with the crystal used by WHAV, having a temperature coefficient of about 20 parts per million per degree C. Thus for a rise of 20°, which is not unusual, the frequency would change by about 230 cycles. $\left(\frac{20\text{cycles} \times 20^{\circ} \times 10^{6} \times 580}{.5 \times 10^{6}}\right) = 230$ cycles

This would give us a beat note with any other station on 580 Kc (there is a powerful Cuban station which does give a beat note) if the crystal were exactly 580 at 23° C.

The other reason for installing the 6C5 oscillator was to increase the driving power. The crystal alone was not exciting the Class C amplifier to a proper value of maximum grid voltage, called E_{max}. For best class C operation this should be 12% of the D.C. plate voltage. The power supply delivers 350 volts, 12% of which is 42 volts. The class C amplifier should be biased to twice cutoff, or as may be determined from the tube characteristics given in the tube

manual for the 6L6, -105 volts. (cutoff for plate and screen at 350 volts is -52.5 volts.) Thus the driver must supply 105 + 42 = 147 volts peak. The crystal will only put out about 50 volts, hence proper operating condition could not be realized. This led to underbiasing, and larger harmonic content in the radiated wave. This was demonstrated by a cataloging of the harmonics up to 30 megacycles, several very strong ones being found as high as 25 megacycles. The list of these harmonics is given in Table 1; they were recieved and cataloged on the RME69 in the studio, only a few feet from the transmitter. Naturally most of these harmonics do not carry, but they make reception on the RME for rebroadcasting short-wave very difficult. Harmonics as high as the 5th have been recieved in Founders with sufficient clarity to listen to them easily. This is true with the 6C5 too, and it is hopedthat in the near future a 6F6 may be used as a driver. It would require ~~only the addition of a screen dropping resistor and condensor~~ no circuit changes except connecting pins 3+4 of the tube socket. *

To measure the operation characteristics of the Class C amplifier several vacuum tube voltmeters were constructed. These are shown in the Figure 9 p 12 later in the paper. E_{max} was measured as 45 volts. E_{min} varied from a negative voltage (with respect to cathode) when there was no load on the tank circuit to +145 with the antenna tuned. The feeders to Lloyd and Barclay were taken ~~off~~ from the ends of the antenna tuner coil at this time, and the tuning was not critical. It was

* this was done with no noticable improvement. - Mayb

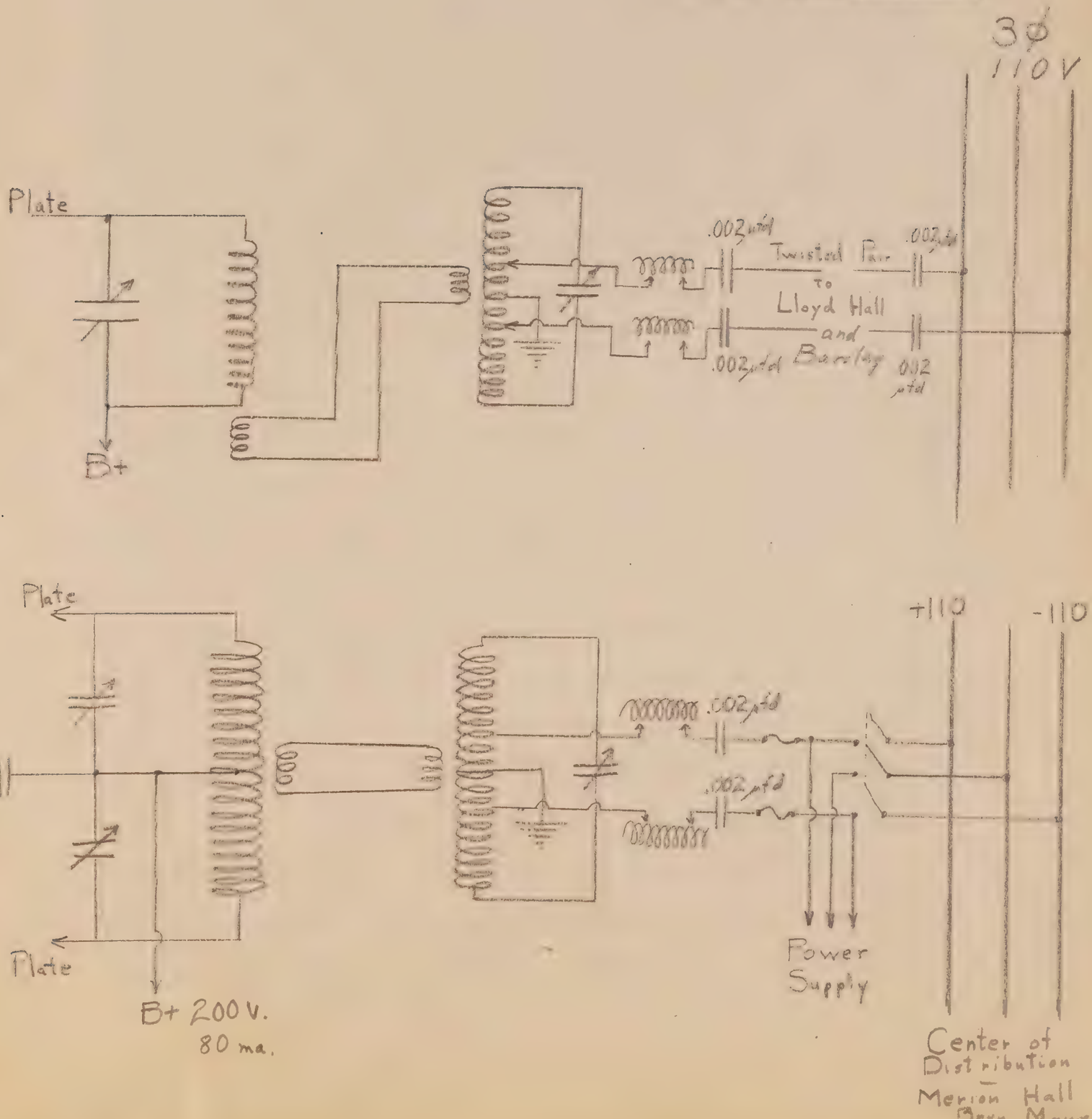
decided to tap the antenna coil up to the proper value of E_{min} which should be 15% of the B+ supply or 52.5 volts. The antenna coil was rewound with #22 enameled wire, making possible scraping and soldering at any point on the coil. Then it seemed that it might be advantageous to tune the condensers which feed the lines to the dormitories. The condensers are .002mfd., the coils were found to be about 25 turns of # 28 close wound on a tube socket. These coils were wound with a tap every turn for the first five, then every five for fifty turns; they were individually tuned to resonance with the .002 mfd condenser by driving them with a link coupling and putting a lamp in series with the coil and condenser. The best place for the taps on the tank coil (giving E_{min} = 50 v) was six turns on either side of the center tap, which was grounded for balance, helping to prevent radiation. Whereas it was found necessary formerly to tune the antenna constantly during a broadcast, this change completely banished this need. The reasons for tuning when the feeders were connected across the tank are probably due to the changing load presented to the ~~modulator~~ Class C Amplifier as more and more of the lights are turned on during the evening. The load changes its phase angle as seen by the input too, causing detuning. When a small part of the impedance of the antenna tank is presented to the line, a change in line impedance does not have very much effect on tuning. The plate tank was rewound with #22 enameled wire to give a higher Q and less power loss. The links were replaced for the same reason. In late April the RF oscillator coil

Fig. 4

WHAV

ANTENNA TUNER

HAVERFORD AND BRYN MAWR



was replaced and both coil and condenser mounted in a #10 tomato can salvaged from behind the kitchen. This prevented coupling between the 6L6 tank and the oscillator tank which might well lead to parasitic oscillation.

It was known before regular operation started that feeding the power lines thru condensers for transmission of RF led to hum modulation of the signal. This was found particularly bothersome on the line to Barclay, since the RF was fed into the power mains right in the studio. One of two things caused the hum - either RF feedback thru the power lines back into the modulator and transmitter, or direct hum modulation of the plate current of the 6L6. It was found that this effect was lessened by isolating the RF feeder from the power lines. This was accomplished by running a line from the transmitter downstairs to the fuse box and tapping in there thru dcndensers. The Lloyd line never did cause much hum. This practice was continued until the advent of the PMs. It was then decided to make use of the several dead lines between the Union and Barclay to feed RF. Formerly the signal had been taken in the basement of Roberts from the power wires for the Union and fed thru condensers into a dead power three wire system (using only two of the three), which was fed, again thru .002mfd. condensers into the hall light circuit in North Barclay. By employing the twisted pair that is strung from Roberts to the Union for P.A. system in event of an overflow in Roberts Hall, we were able to feed the RF signal back stage in Roberts, from which it

was only a short distance to the dead pair in the basement. This proved to give excellent reception in Barclay and no trouble has been had from that circuit since, except the proximity of the feeder to the antennas of the RME in the attics of the Union. A future project will be the moving of the line from the transmitter to Roberts so that it passes around the second floor level and stays away from the RME. It now causes peculiar effects on the RME such as providing a 456Kcycle beat note with all stations 456 Kc from any harmonic of the transmitter, many of them strong enough to get thru the RF stage and cause squeals.

The transmitter and modulator were removed from the booth about Christmas time and placed in the second room. This has proved much more satisfactory, allowing the RME to be in the booth, and facilitating work on the transmitter and modulator. The line feeding the modulator from the pre-amp was twisted pair, with a high capacity, and ### connected directly to the grid of the 6SC7 in the modulator. This line cut the high frequency response and the solution that has been reached is putting the modulator in the booth and feeding the power to the transmitter over twisted pair. This works quite satisfactorily. The modulation transformer which had been mounted on the transmitter was changed to the modulator so that only two wires need be run to the second room.

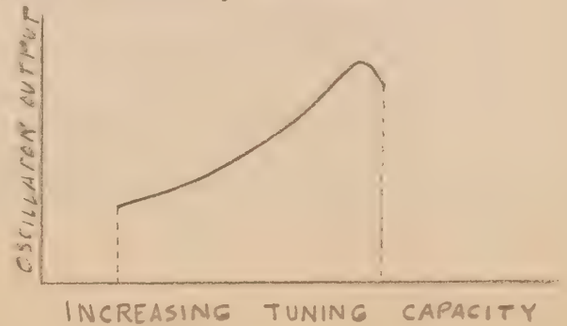
An RF choke is usually placed in the grid of a class C amplifier. It was noticed that conditions did not change when the one in the 6L6 grids was shorted. The explanation

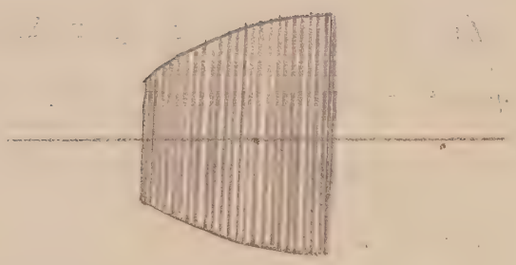
is found when we calculate the reactance of the choke at 580 Kc. $X = 2\pi fL = 6.28 \times 580000 \times .0025 = 9100$ ohms. Since the grid leak is 40,000 ohms, this has little effect on the RF signal fed to the grid. Consequently it was removed. Proper operation would call for a 25 - 50 millihenry choke, which would have a reactance of 90000 - 180000 ohms.

A cheap Read-rite milliammeter in the plate circuit of the 6L6 was demagnetized by a momentary overload. In this type of meter, a stationary coil carries the current and its magnetic field exerts a torque upon the small magnetized armature. An attempt to remagnetize this armature was only partly successful, but might easily be done by passing a series of large surges of current thru a coil of #26 wire wound on the armature. Several amperes should be used, but if continued will burn out the coil.

With the new methods of coupling, hum in the transmitter is very small. The modulator has a hum noticable in the RME but this may not be coming over the air. Hum does strange things and may be induced into the radio frequency signal right in the radio. For instance, turning on the pre-amplifier always introduces a hum on station WCAU, but on no other station. No satisfactory explanation of this has been reached.

In regard to the tuning of the transmitter, several items are worthy of note. The first is the response of the crystal as the tank condenser of the 6C5 is rotated.





Amplitude Distortion in
Class C Amplifier
– strength of R.F. wave not proportional
to plate supply voltage –

Starting at minimum capacity, where the crystal will usually oscillate if the load is not heavy, the response or voltage output of the oscillator increases to a maximum. This is where the tank is at the resonant frequency of the crystal. Shortly beyond this point, that is with more capacity, the crystal ceases to operate altogether. The explanation reached by the author is the change in the phase angle in the tank. With more capacity than that for resonance, the current in the tank (A.C.)leads the voltage. This delays the voltage applied to the capacity from grid to plate (in the tube) and shifts the feedback causing oscillation until it no longer occurs. With a lagging phase angle, however, the voltage,being ahead of the current, is applied to the crystal in such phase as to sustain oscillation.

Illustrating the fact that the 6C5 does not have enough power output, the tuning of the plate tank of the 6L6 is also critical with respect to sustaining oscillation. If the 6C5 tank is at the peak, near the cutoff value, rotating the 6L6 tank may stop oscillation by drawing a heavier load from the 6C5, lowering the AC voltage in its tank and lowering the feedback voltage below the critical value.

When first constructed, the tuning of the antenna tank seemed critical with respect to distortion. The only reason the author can find for distortion in the audio wave as heard in the reciever is amplitude distortion produced in the 6L6 because of non-linear response. With a cathode ray scope this would give a barrel shaped trapezoid as shown opposite.

The method of obtaining trapezoids and their usefulness in studying class C operation will be discussed in the section on monitoring. This distortion effect is not present now, since the new antenna tuner has been built.

One of the most puzzling facts in the entire year was stumbled on in mid January. There is a monitor speaker connected across the modulation transformer in the middle room so persons working or waiting in this room may hear the programs. In an attempt to improve the response of the 6C5, somehow the dials on the plate and antenna tank became far detuned. When the 6C5 tank was rotated a very raucous noise was heard in the monitor speaker, then the strains of Beethoven's Fifth Symphony came out, not without some distortion. The first thought was that someone in the next room was playing it with the modulator turned on. This was not the case however. Possibly we were picking up one of the commercial stations - for some reason. We tried them all but the programs did not coincide. We waited for the end of the symphony, expecting that someone in Lloyd was playing a phonograph oscillator. One may well imagine the surprise on the faces of those in the room when the symphony finished and a polished voice announced that we were listening to W69PH, the F.M. station owned and operated by WCAU, Phila.

In view of the complete lack of an explanation, further data was sought. With careful tuning, W49PH and W53PH were also received. By broadening the tuning of the tanks with coils (short circuited) placed inside them, the fidelity was

improved. The condensers were best tuned with a mailing tube about two feet long, to eliminate hand capacity. Also noticed 1) Disconnecting the RF feeders had some effect but only changed the tuning. 2) No wire including the ground was acting as an antenna, since it worked with all disconnected. 3) Many changes in the circuit have not stopped the phenomenon. Different coils, shielding all coils, different plate voltage, removal of RF choke in grid circuit, changing the antenna tuner, etc. did not change the effect. 4) as mentioned, short circuited coils placed in the tanks made a definite improvement in the fidelity. 5) bringing the hands near the circuits had great effect, on tuning and volume of the signal. The problem was discussed with several men who should know, but could not explain the phenomenon. Among these were Mr. Benham, Mr. Littlejohn, chief engineer of W53PH, and Mr. Robinson, consultant engineer for W49PH.

A tentative theory has been worked out by Mr. Thomas and the author, but no means of verifying it has been found. They suggest that the FM signal, at a frequency of 46.9 Mc. in the case of W69PH, is beating with one of the higher order harmonics of the 580Kc crystal. The existance of these harmonics was shown earlier. The beat note is then tuned in on the tank of the 6C5, and amplified by the 6L6. Since FM stations use a deviation of frequency of 150 Kc., the beat note will likewise vary by 150 Kc. This is a substantial variation at about 600 Kc and accounts for the improvement with lowering the Q by inserting coils. The reason for hearing the signal in the monitor speaker is due to the non-linear response to such

widely varying frequencies, and this is the only reason that the signal is detected at all. Naturally this modulates the plate current of the 6L6 and therefore is heard over the air. W69PH was broadcast by WHAV for several hours one evening as a test. It was found that reception on a reciever that was not very selective, such as a small TRF, was quite good. Due to the frequency deviation, however, superhet reception was unfortunately poor. It is hoped that this theory may be verified in the future. It is a type of superhet reception that, to the author's knowledge,has never been used. That is providing a constant frequency to beat with the stations, and tuning the I.F. amplifiers. It is not as practical as normal superhet practice, where the oscillator frequency is varied to provide a constant I.F. #

Concerning the method of feeding RF to Lloyd and Founders, it might be wise to mention the connections in the basement of Lloyd. The lines were tapped into the cellar lighting system under 9th entry at the beginning, always thru .002mfd. condensers to prevent the 60 cycles AC from traveling in the twisted pair feeders. Reception in Founders Hall was weak and something had to be done. The basement lighting circuit was taken from the 6th entry pair of power feeders. The power comes from the transformers in Founders as 3 phase, 115volts, 60 cycles. Obviously only two of the three can be fed RF. It was found that the pair in 6th entry provide the poorest reception in Founders. Either of the other two combinations is better - seeming to indicate by symmetry that the pair in

sixth entry is the same pair that feeds the Founders rooms. This was a surprise to the author, who thought that it would be best to feed RF into the pair leading to the desired spot. Apparently, it is better not to balance the signals or they will cancel out . The RF feeders are now connected to the pair feeding entrees 7, 8 and 9, under sixth entry.

The Modulator

At the beginning of the year, WHAV used a 14 watt HI-FI amplifier for modulator, belonging to the author. The circuit is identical with that of the present modulator, with the addition of a 6SJ7 microphone input on the original that was omitted in the WHAV modulator. The circuit for the latter, Figure 6 , was drawn up from plans used on a Knight amplifier. A choke filter was added in the B+ lead to cut the hum. The potentiometer input was turned around for several reasons. One was due to the fact that the lead to the modulator was taken from the grid of the 6C5 in the pre-amp, and fed thru a condenser to the tap on the input potentiometer. Thus turning down the volume acted as a tone control, shorting out the highs thru the coupling consenser. Also the volume was not proportional to the angle of the potentiometer, being nearly to full volume after only $\frac{1}{4}$ of a revolution.

The 6SC7 phase inverter operates as follows. The signal is fed to grid #1 (pin #4), is amplified and applied to the grid of one of the push pull 6V6s. In order to get a voltage exactly 180° out of phase with that applied to the first 6V6, which is needed for the grid of the second 6V6, a portion of

that voltage is taken off from the grid leak by the voltage divider formed by the .5 mg and .1 mg resistances in series. This voltage is applied to the other triode unit in the 6SC7 and amplified. Since the phase shift in a resistance coupled amplifier at its middle range is 180°, the output of this tube is what is needed for the other 6V6. Of course, the frequency range of the inverter must be wide since the phase shift at cutoff is 180° ≠ 90° and this would produce bad distortion in the push-pull circuit. Two kinds of negative feedback are employed in this amplifier. The .5 mg. resistors from 6V6 plates to 6SC7 plates cut down the gain somewhat, but greatly decrease distortion, and improve the frequency response. The fact that the grid leak of the second 6V6 is returned to the grid of the phase inverter is another form of negative feedback or degeneration. It makes the amplification of the inverter dependent on the feedback factor β determined by the .5 and .1 mg resistors, thus this circuit will stay fairly well balanced despite the amplification of the inverter, that is the signals applied to the 6V6 grids will be equal. This is known as balanced phase inversion.

The operation of the tone control will be described in the section on frequency response, as will the frequency response of the whole modulator.

The 6V6s are rated at 14 watts output; as shown in Terman,[1] the power needed to plate modulate a class C amplifier 100% is one-half of the power input to the class C amplifier.

F.E.Terman, Radio Engineering, p399

The RF input power is 350volts times 60 ma = 21 watts. Thus 10.5 watts are needed, and should be supplied by the modulator. To test this, the modulator was removed to the Physics Lab. Replacing the transmitter with and equivalent load resistance, which may be calculated as $\frac{350}{.06}$ = 5800 ohms, the wave form and voltage output were observed on a voltage calibrated oscilloscope. The input was fed with an audio oscillator, and the gain increased until distortion was noted in the output wave. There are two good ways to test for distortion in an amplifier with an oscilloscope. 1) If the input signal is applied to the horizontal amplifier and the out put to the vertical amplifier of the CRO, a straight line should be the result. If any grid in the amplifier is driven positive, or if any grid of a single ended (as opposed to push-pull) amplifier is driven negatively beyond cutoff, the line will no longer be straight, but will flatten out horizontally at either end. 2) The output may be applied to the vertical amplifier and the internal sweep in the CRO made to spread out the pattern. A critical eye can tell the appearance of distortion here as easily as with the other method. It will usually be a flattening of the peaks.

Since the CRO is calibrated in voltage RMS (root-mean-square), the voltage applied across the 5800 ohm load resistance may be measured. V^2/R gives the power output, and it was found that the maximum undistorted power output was <u>eight watts</u>. This is not sufficient since 10.5 watts are

needed for 100% modulation. On the basis of the findings of this experiment, the transformers of the transmitter and modulator power-supplies were exchanged. This raised the power output of the modulator undistorted to about 9,5 watts and lowered the input power of the class C amplifier to 17 or 18 watts, depending somewhat upon the tuning. Thus the combination may work at 100% modulation. If the screen dropping resistor, now a pontentiometer, in the class C amplifier were changed to a resistor, this would decrease the input power about 2.5 watts. Has been done The value of the resistor may be calculated approximately but should be adjusted to give a screen voltage of about 290 volts. Since the plate current of a pentode is relatively independant of plate voltage, the screen voltage must be modulated too. Therefor the value of the screen bi-pass condenser, as well as that of the plate is limited, so it will not short out the higher audio frequencies. Neither should exceed .001mfd.

The load that the modulation transformer sees when looking into the class C amplifier is given closely by the formula E_b/I_p , or as mationed earlier, 5800 ohms. This must be matched to the 7000 ohm plate to plate impedance of the modulator, and this is done by choice of taps on the modulation transformer as shown on the accompanying instruction sheet.

The Pre-amplifier

Probably no part of WHAV has had more attention, and more changes, than the pre-amp. The original circuit was a modi-

fication of one given in the Thordarson Amplifier Guide. WHAV wanted two mike and two phono inputs, separate volume controls for each, and a single stage of amplification to put out about 4 or 5 volts maximum. This was accomplished with two 6F5 mike amplifiers and a 6J7 triode connected as the amplifier. The output of the 6J7 was fed thru a condenser to the modulator and thru a transformer to earphones for the engineer. The earphone signal proved to be too weak for decent monitoring and since hopes were running high for a telephone line to Bryn Mawr, it was found necessary to add another stage of amplification. The 6C5 was chosen because it would put out plenty of power for earphones and the Bryn Mawr line, and because it has a 6.3 volt filament. The output transformer was shunt fed from its plate.

The two phonographs had drastically different frequency responses. The Shure produced more base. The cure for this is smaller resistance across the input. After trying various values as recommended on the specifications included with the pickup, the value of 200,000 ohms was chosen as giving a response closest to that of the Astatic pickup. Since series resistance attenuates the high frequency, the ideal system would be to feed each phonograph into a separate triode amplifier and combine and mix them in the output. In that way the input resistance would be constant and could be adjusted much more critically. This is known as electronic mixing.

For playing the phonos it was found that grinding the

volume controls up and down took time and did not produce continuous fading between one record and the next. A switch was installed to short out the phono not in use, and mounted on top of the pre-amp for convenience. This produced no "popping" sound when thrown from one to the other, whereas a switch that broke the circuit did "pop".

The pre-amp is now mounted on a hinged table which swings down in front of the engineer. This is the only possible arrangement with the single entrance booth. The output to the Bryn Mawr line and to the modulator are taken thru a 5 prong plug. The phono inputs are pin jacks and the mikes are Amphenol mike connectors. A phone plug on top of the pre-amp from the 250 ohm winding on the transformer is used for phone monitoring. Since the 500 ohm winding is used for the Bryn Mawr line, the load put across the 250 ohm taps should be high impedance. The earphones used have several thousand ohms impedance and do not affect the line. A type 71-A power amplifier was added for studio amplifier, and will be discussed under the section on monitoring.

The R.M.E. 69 - use and servicing

It became apparent after some use that the RME receiver was not picking up the distant stations as well as might be expected. The BBC rebroadcasts were not good, and were well mixed with static. No instructions on servicing it were in the possession of the engineering dept, so a request was made to the Radio Manufacturing Engineers, Peoria, Ill. for a

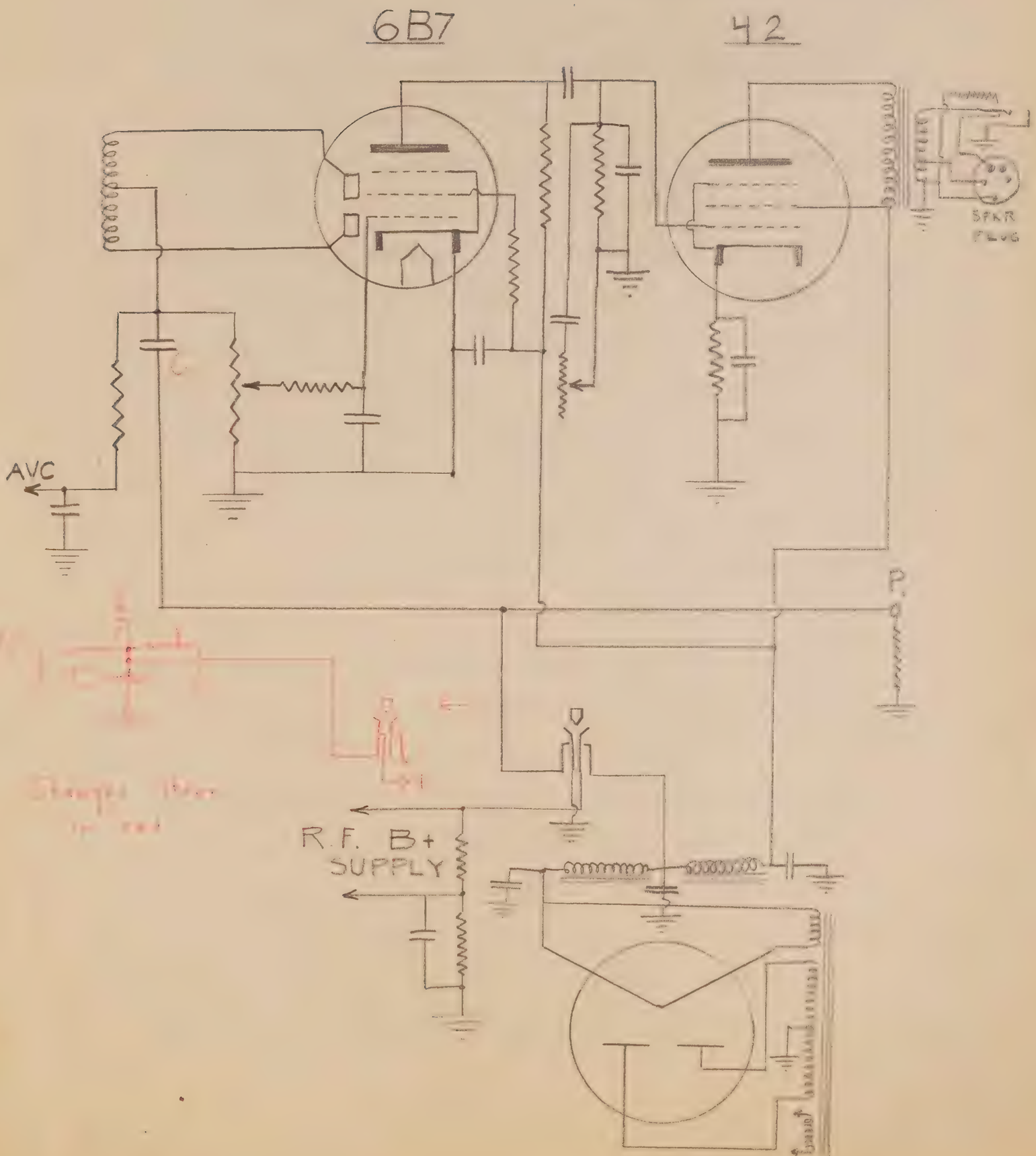
Fig 3

WHAV

RME APPLICATION

AS

AUDIO AMPLIFIER



service manual. When it arrived, the job of lining up the I.F. began. Fortunately, no signal generator is needed, since the crystal control in the grid of the first I.F. sets the frequency at 465 Kc. It was found to be far out of line, so badly, in fact, that no signal was received with the crystal in series with the grid of the first IF amplifier. The broadcast band was also aligned.

It is desirable to have several kinds of antennas. For broadcast band reception a single long antenna is best, since the RF amplifier is voltage fed on band #1. On all other bands, the antenna lead-in goes in thru a coil in the receiver which is coupled to the grid tuned circuit, and back out to the second post on the receiver. Thus either a doublet or current feed single antenna is necessary. The latter is accomplished by grounding the middle terminal and feeding the singlet to the first post. For the doublet, a 31 meter tuned doublet is the most practical. Each arm should be $\frac{1}{4}$ wave length long, or $7\frac{3}{4}$ meters, or 25.4 feet long. The present doublet is not exactly this length but should be extended. The ground used for the entire station is the heating system and is not causing any trouble. The 31 meter doublet is now installed. Man

The audio system of the RME is quite good, shown in figure 8. It was hoped that it could be used for the engineer to monitor with; the switch on the front cuts the B plus of all RF stages to silence the receiver when sending. There is a post on the back of the receiver which feeds to the center tap of the detector transformer, used for monitoring

the transmitter. Obviously, any audio signal fed into this post would be applied to the grid of the first audio, the 6B7 pentode amplifier, and would give an audio system. The condenser, C was permanently grounded as RF bi pass ~~had to be enlarged to pass audio frequencies~~, and the silencing switch was changed so that it broke the circuit on this input rather than grounding it thru C when the receiver was in use as such. There is only one difficulty with the system - the bias on the 6B7 is provided by the rectified signal, thus preventing ever driving the grid positive. But when the signal disappears, so does the bias. Distortion was unbearable. The only way to avoid this would be to put in a bias cell which was connected whenever the silencing switch was pulled.

In need of a studio speaker for the monitoring and enjoying of the programs being put on the air, temporarily a pair was tapped onto the 8 ohm voice coil of the PM dynamic speaker on the RME and fed to a studio speaker. This was quite unsatisfactory because the RME was needed to check for overmodulation by detuning and to receive BBC for rebroadcasts. The 71-A was added shortly and ended that trouble.

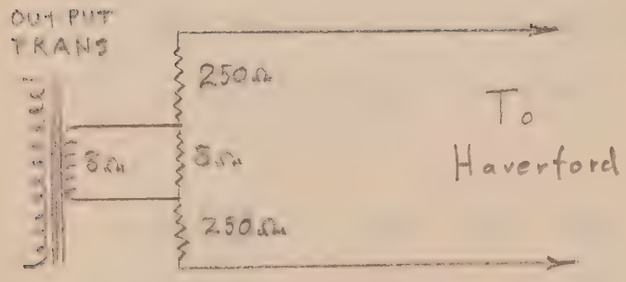
Remote Broadcasting Problems

It is often desirable to broadcast a program that can not originate from the studio. For instance any program requiring a piano must be done from elsewhere. Even if WHAV was given a piano, it would not be possible to get it to the

third floor of the Union, or into any of the rooms, once up there. Most of the furniture now in the rooms had to be taken apart to get through the narrow gauge doors. Also any program with an audience must be done from Roberts. The Glee Club, the Band, and plays must be sent in from some more suitable spot than the studio.

The first remote that was broadcast was the Glee Club singing in the auditorium downstairs. Let it be recorded here that that room has an echo period of several seconds, and must never be used for the glee club, unless sound-proofed. That remote was quite simple, however, since only 50 feet of mike cable were needed. Later broadcasts from the same hall have shown it to be satisfactory for piano recitals, the mike preferably being covered with wadding to decrease the sensitivity and placed near the back of the piano. A jazz band was also broadcast from there with fair results.

The first real remote came from Bryn Mawr in early December. It was desired to broadcast the dress rehersal of the play "Hotel Universe" from the stage in Goodhart. No portable pre-amp was available; Bob Harper changed over his radio, which operated on the DC which is univeral at Bryn Mawr, so that it could be used as a preamp. The only difficulty was that no transformer was had that would match the plate to a 500 ohm line. A proper match was obtained with two 250 ohm resistors in series with the line, tapped across the voice coil of his speaker. This wasted considerable



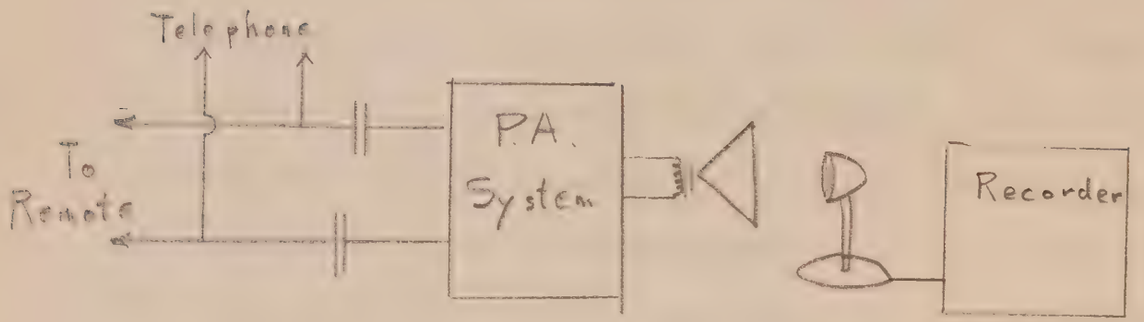
Matching Voice coil
to line -

power and reception at Haverford was poor. The phone line at that time was being used to drive a phono player in the common room, and the engineers learned some of the not to be forgotten facts about line impedance matching. It was noticed with alarm that merely connecting 150 feet of twisted pair across the line and leaving it open at the end raised a racket in the line, due to reflection from the open end. A transmission line, of any considerable length, must be terminated in its characteristic impedance. The characteristic impedance of a line is determined by the wire diameter and spacing; if a transmission line is terminated in its characteristic impedance there will be no reflection of the current traveling down the line, that is, it will be totally absorbed. The input impedance to the line will then be the characteristic impedance also. The maximum power is transmitted when the line is thus matched.

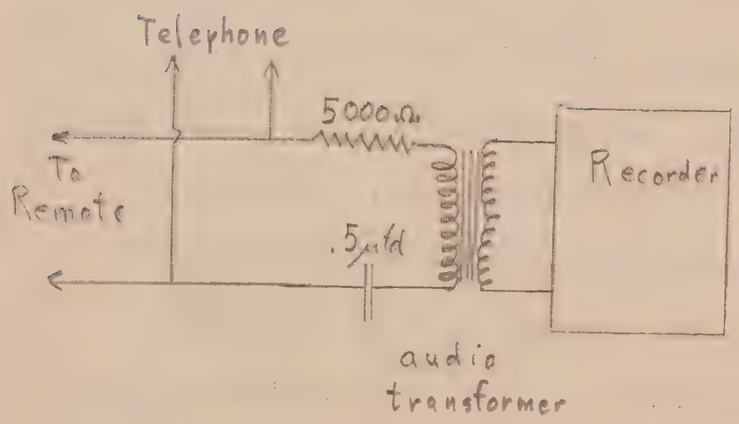
Another broadcast from Bryn Mawr came on Sunday night, December 13, 1942. The regular chapel service at 7:30 pm with the choir and a speaker was presented. This time the engineers had the problem solved in advance. Since no part of the program was to originate from Haverford that evening, the entire preamp was transported to the music room at Bryn Mawr. The announcements at the beginning and end of the program were made at Haverford by using the author's amplifier with mike input. Two mikes were used at Bryn Mawr and the program was quite satisfactory. As usual, monitoring difficulties were encountered, since no

Recording Telephone Messages

(1) Used on Hamilton Game



(2) Approved Method



volume level indicator was used. Consequently on parts of group singing of hymns the distortion was high. This need for a volume indicator has become more apparent with each broadcast.

A rather different type of remote broadcast was tried when Haverford went up to Hamilton College to defeat them on the gridiron. Between the halves and after the game, two special reporters telephoned messages down to Haverford, having taken extensive notes during the game. At this end the phone wire was tapped and played over a P.A. system, into a microphone, and recorded. The method might have been improved by feeding from the line directly to the recorder, and by subduing the noise around the telephone instrument. The recordings were quite understandable, however, and were played back to the sports board, sentence by sentence, until it had all been transcribed to paper. These reporters then went to the studio and reconstructed a play by play description of the entire game, the second half coming after supper.

Another method for remote broadcasting from short distances, such as one of the rooms in Lloyd Hall, has been successfully employed. Again using the PA system belonging to the author, one side of the 8 ohm voice coil was grounded, the other side sent thru a wire strung for the purpose from the studio to the location. An eight ohm load resistance must of course be substituted for the speaker. In the studio, the wire is connected across and 8 ohm resister to ground. From the top of the eight ohm resistor a 500 ohm resistor

Remote from Robert Hall is outside. The P.A. system in Roberts is used, and the plug back stage near NE exit is plugged in to send signal over to Union on the R.F. feeder. One side of the R.F. feeder is then connected to the phone input on the Pre Amp. No detection of the R.F. has been noticed.

It is just above the wall plug in Robert Hall R.F. was stopped off to go to Bandag. The socket goes to the front of Roberts to the Union. The plug comes from the output of the PA system. This plug should be removed from the socket when finished as one side of the output transformer on the PA system is grounded and detunes the antenna tuner.

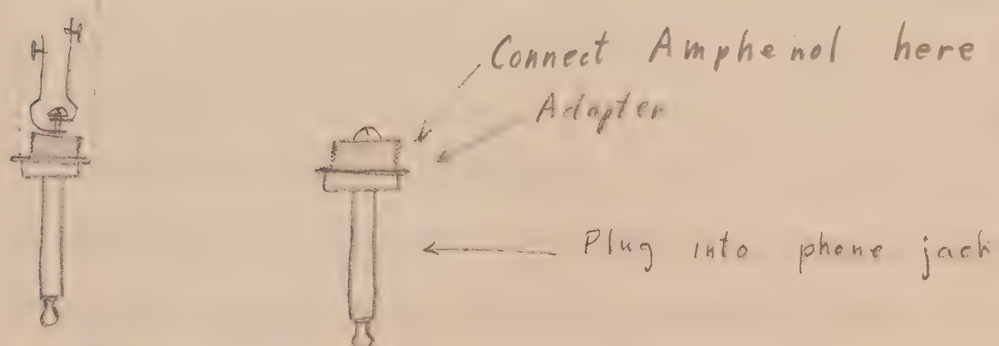
Dr. Reynolds was broadcast with D. Kelly accompanying him on Wed. night, May 12. The studio audience of about 40 was the first WHAV had. Clapping sounded good. The P.A. system has bass and treble boosters. The bass was set to 2 second reading, the treble at 3. This gave excellent fidelity transmission.

went to the line to grid transformer, matching it. This works quite well on distances up to 500 feet, above which hum is picked up since the line is single and not balanced. The parts are in the stock piles of WHAV to build a portable pre-amp; the only item lacking is a transformer to match plate to line and its purchase, though possible, is not probable this year.

The subject of remote broadcasting seems to include that of rebroadcasting from the air waves. There are several items of interest here. As has been mentioned, the BBC was rebroadcast quite regularly for the first 4 months of WHAV's operation. Programs proved to have little value and were discontinued. The method is very simple: the RME has an earphone plug, and this is fed to one of the two phone inputs. About eight different BBC stations were accurately logged for the engineer to find at a moments notice. Occasional interesting German and Italian propaganda items were also rebroadcast

In rebroadcasting from the air, one must keep in mind that there is no point in rebroadcasting what any radio can receive. For this reason the engineering department has consistently refused to rebroadcast standard programs such as Fred Waring and Harry James. There are programs and stations worth listening to which the average radio is incapable of receiving. WQXR, the high fidelity station in New York, presents classical music programs most of the time and is hard to get on most radios in this locality.

Recording may be done in the studio of any program. The output jack used for the engineer's phones is the best place to take the signal from the program. A connector must be used having a female amphenol with connector on one end and a plug on the other. To get the, use the Electrovoice Dynamic microphone cord, having female amphenols at both ends. Take a phone plug apart (remove the lugs used to connect phones) and the female amphenol will fit it perfectly. The records is borrowed from Mr Gibb. B.M. Sire. must be plugged in to mated the transformer



The RME at present does not receive it well either, but with an aerial running NW and SE, from the studio to the roof of Lloyd Hall, of length 155 feet, reception should be good. This 155 feet is ¼ wave length at 1560 Kc, the frequency of WQXR. Has been done - better

The third and most promising rebroadcast is that of F.M. programs. There are four F.M. stations in Phila. and there is always classical music. Here the only problem is the obtaining of a suitable receiver. With wild hopes, the author wrote to W53PH concerning permission to rebroadcast the programs, and mentioned the difficulty of obtaining a receiver. It was hoped that the sponsers of W53PH would be interested in increasing their audience by some thousand students, interested enough to give or lend to WHAV an FM receiver. The chief engineer, Mr. Littlejohn, promised to lend us a receiver, but backed out later. Thomas, Gray and Severinghaus enjoyed and learned from a visit to the studios of W53PH. Mr. Littlejohn spent more than an hour showing them the station from top to bottom, and explaining some of the intricacies of phase modulation.

Several stores in Philadelphia still offer F.M. converters. The best one is the General Electric, selling at $37.50. The tube line-up includes and RF amplifier, mixer, two IF amplifiers and a cascade limiter, and a detector. For about $29.00 a Brewster converter offers a tuning eye but only a single stage limiter. It is the limiter in an FM receiver that gives it part of the advantage of no noise or static.

At present the problem is not to find suitable programs, and the purchase of an FM receiver may well wait till WHAV is assured of technicians to keep the station in operation.

One of the best methods of remote pick-up for occasions around the campus would be use of carrier current frequencies around 150 kilocycles. With a suitable receiver, these bands are clear and small power will travel for long distances on the wires. The original phono oscillator of WHAV is still workable and might be changed to cover this band. The RME does not go below the broadcast band so either a receiver that does would have to be obtained, or a converter built. The latter might prove easier.

FREQUENCY RESPONSE MEASUREMENT

Once the station is operating smoothly, and is receivable where it should be, the question becomes "How good does it sound?" The term Hi Fidelity is undoubtedly overused, but stands for a character of transmission which should include frequencies up to 7500 cycles. The commercial station is limited to 5000 cycles because of the fact that higher frequencies cause wider side-bands, thus spreading the station out. If this limit were not imposed, fewer stations could operate on the broadcast band. No such limits are imposed on a carrier current station, since no license is required by the Federal Communications Commission. Every effort should be made to transmit a band width of 8000 cycles, especially if FM is to be rebroadcast. For these reasons

it was decided to determine the frequency response of all parts of the station.

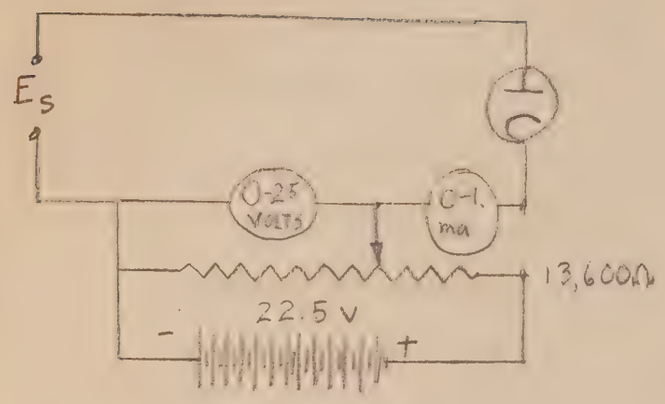
The equipment was borrowed from the Physics lab and some was constructed. The most important item is a good audio frequency oscillator which will produce a true sine wave of constant amplitude over a range of 30 - 15,000 cycles. Such an oscillator belongs to the Engineering lab. The output was calibrated vs. frequency and found constant up to 9000 and down to 90 cycles. For strictly accurate use beyond these frequencies correction should be made for all readings, or better, the oscillator adjusted to give the same output at all places. The latter would be done by setting the oscillator for the frequency desired and reading its output on the measuring instrument, adjusting its volume to read the standard output, then reading the output of the apparatus in question.

The instruments for measuring the output voltages must have several qualifications; 1) No current must be drawn from the circuit in question, since it is often desired to measure grid voltages. 2) The frequency response must be absolutely flat for all frequencies to be measured 3) It must be adaptable to measure voltages as low as one-half volt and as high as five hundred volts. 4) To eliminate any DC components, it must be capable of being condenser fed. With these considerations in mind, the first choice was to build a suitable vacuum-tube voltmeter. Figure 9 shows several types of slide-back vacuum tube voltmeters which were tried. The advantage of a slide back meter is that

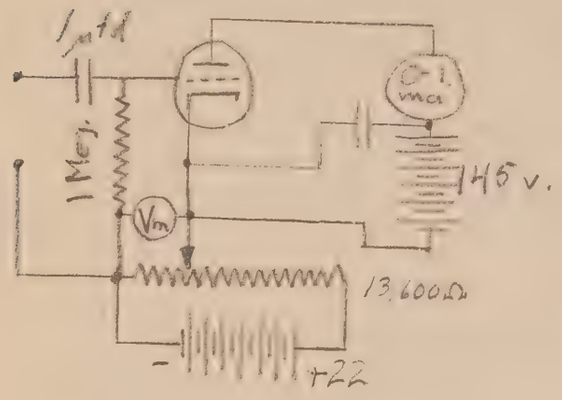
WHAV

SLIDE-BACK VACUUM TUBE VOLT METERS USED FOR FREQUENCY CHARACTERISTICS AND R.F. MEASUREMENTS

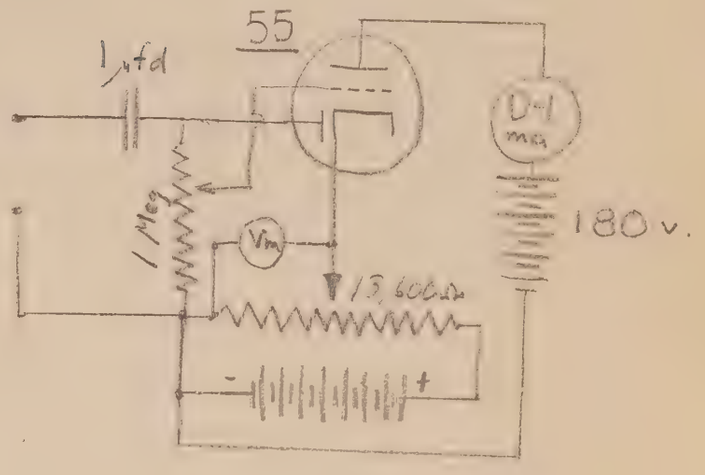
(a)



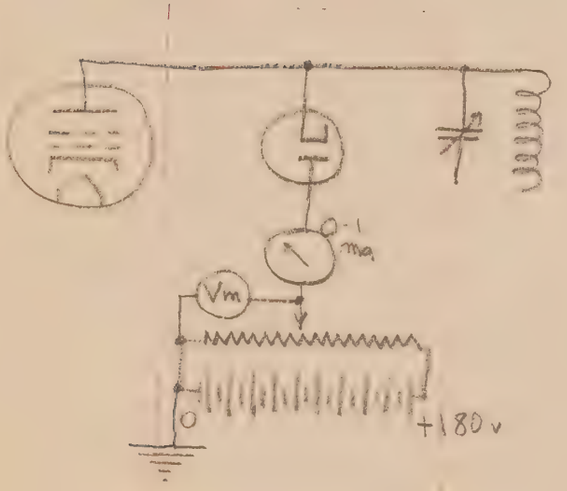
(b)



(c)



(d)



(1) - measurement of E_{max}

(2) (3) - audio frequency measurements

(4) measurement of E_{min}

it need not be calibrated, but reads in volts directly. For the purposes of frequency measurement it is immaterial whether it reads peak or RMS values, since peak always is 1.414 times the RMS value for a pure sign wave.

Figure 9a. is known as a diode - slide-back vacuum-tube voltmeter. The input signal is fed to a two element tube, rectified, and the current sent thru a microammeter. Since one specification was that it draw no current, and another stated above, that it be direct reading, a variable bias is applied to the cathode with a voltmeter to read it. Then for any signal the tube is biased to cutoff and the voltage recorded.

Figure 9b. is the same idea applied to a triode. In this case the cathode is biased until plate current stops flowing which means that the voltmeter will be again reading peak voltages. With very little error, the tube may be biased until the plate current is some constant value, say .4ma. This can be more accurately determined than cutoff and the error due to the change is area under an entire series of sine waves for changing frequency is negligible.

Figure 9c. is a combination of diode and tridde. It has little advantage over the other types for a sign wave, but would be better for a wave with harmonics, since it applies a rectified voltage to the grid. The reading is peak voltage

Figure 9d. is the circuit used to measure the minimum plate voltage on the class C amplifier. Since the tube is inverted, it will not conduct unless the voltage on the cathode goes lower than that on the plate. The plate is therefore biased positively until current begins to flow.

The voltmeter then reads the minimum plate voltage directly. For measurement of E_{max} the slide back circuit shown in Fig. a is satisfactory. The plate of the diode goes to the grid of the class C amplifier, the negative end of the battery is returned to the cathode (not ground if there is a cathode bias resistor.) The cathode of the diode should be bi-passed to the class C cathode with a paper condenser.

The first used slide back meter was circuit a. This was put to use in adjustment of the class C amplifier and its load, being converted to circuit d for E_{min} measurements. It was on the basis of the results obtained that the antenna tank coil was rewound, center tapped, and series resonant circuits were added in series with the line. The taps on the coil were chosen to give an E_{min} of about 50 volts. This is approximately 15% of the plate voltage. With the antenna tank tuned and no antenna connected, E_{min} was about 140 volts. With the link coupling completely out of the tank E_{min} was too small to measure. The taps were soldered on the coil at the tap that made E_{min} the proper value, when the plate tank was tuned for minimum plate current and the antenna for maximum brilliance of a flashlight pick-up loop and bulb. The two points did not coincide: when the antenna was tuned for brilliance of the indicator bulb, the plate current was not at the minimum. The idea is to find the tuning which will give the most brilliant light. That might be called the maximum-minimum of the plate current. Thus when the antenna is tuned, the plate current should go

thru a maximum at the same time. This should be minimum for tuning of the plate tank too. If these points are too far separated it is either because of high resistance in the circuits or overloading of the antenna. tuner. On E min too low.

To return to the measurement of frequency response, the pre-amp was tackled first and will be discussed in full. The 5000 ohm output of the audio oscillator was used on various inputs: all different outputs were tried, and found to be only slightly different. The curves are rather more telling than any words could be to indicate how poor the high frequency response is. The most true picture of the original response is curve #2 shown in red. The curves on the phono input are not as indicative because the 5000 ohm out put of the audio oscillator was being fed to the circuit usually matched with a 500,000 ohm crystal. Thus the high frequency falling off due to capacity to ground in the input would not be noticed. This falling off amounts to 3 db or 70.7% of the voltage when the reactance of the shunt capacity is equal to the resistance across which it is shunted. The input resistance of the 6J7 is 130,000 ohms when only one circuit is being used. Thus a falling off to 70.7% at 7000 cycles would be due to a condenser with 130,000 ohms reactance at 7000 cycles, or .000175 mmfd. This is a small capacity and might easily exist in the network of shielded wire on the input of this tube. This shielding may be unnecessay and its removal for trial is suggested.

KEUFFEL & ESSER CO., N. Y. NO. 358-63
Semi-Logarithmic, 2 Cycles × 20 to the inch.
MADE IN U. S. A.

Severinghaus, J. W.
March 18, 1943

Note on curve 10 and following: June 1. It was found that the cathode condenser on the triode 6 J 7 had been originally installed with the negative end at the grid. This explains most of the trouble in the back of the curves up to #10. After correcting this, only the large input capacity lowers the response.

KEUFFEL & ESSER CO., N.Y. NO. 358-63
Semi-logarithmic Cycles × to the inch.
MADE IN U.S.A.

Severing Hens, J.W.
March 18, 1943

WHAV

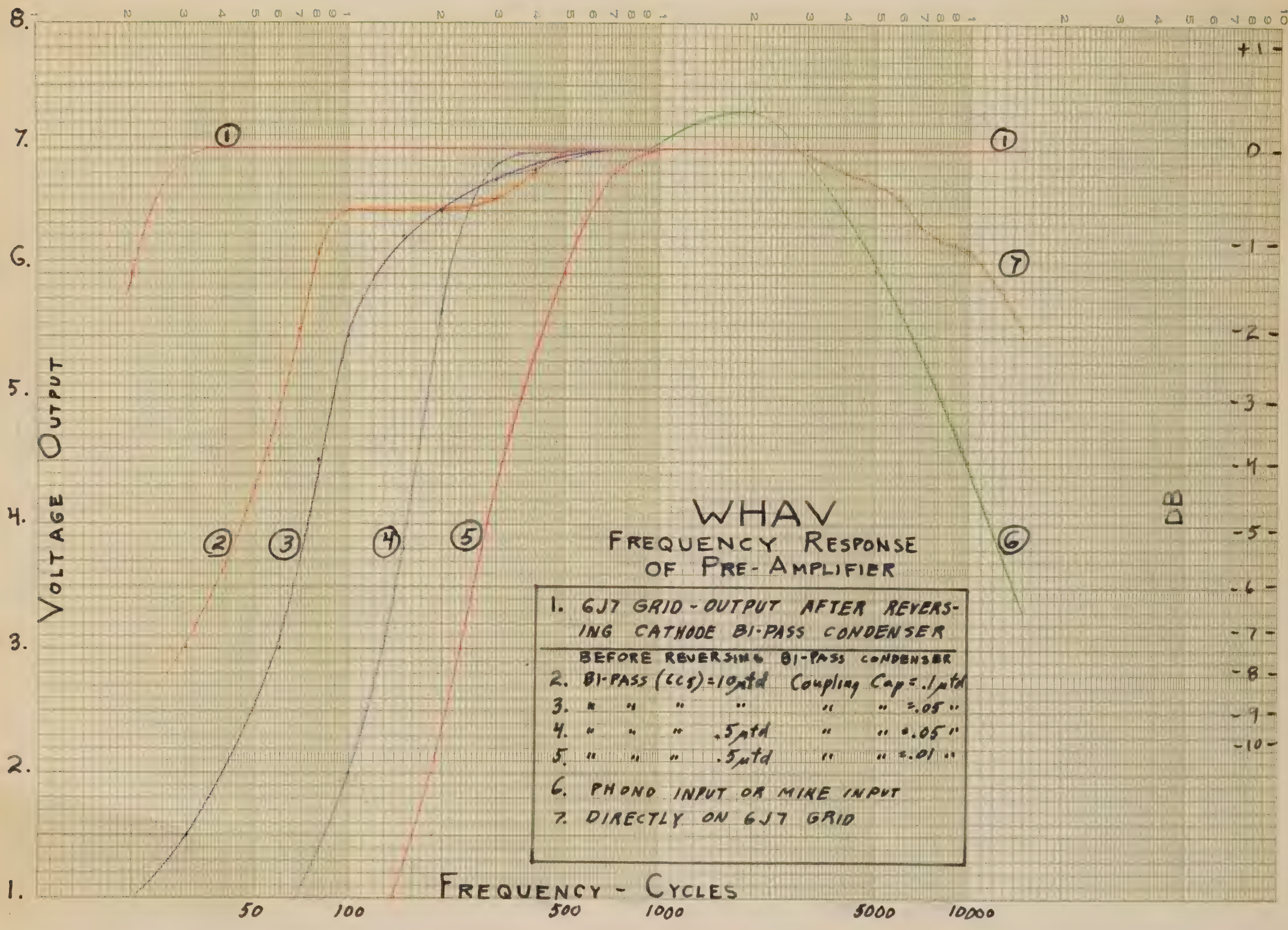
FREQUENCY RESPONSE OF PRE-AMPLIFIER

CURVE	INPUT	OUTPUT	6J7-6C5 Cc = μfd.
#1	MIKE #1 @ 45	6C5 GRID	.01
#2	MIKE #1 @ 45	LINE TO MOD.	.01 .5 μfd.
#3	PHONO	" " "	.01 "
#4	MIKE #1 @ 45	500 Ω OUTPUT	.01 C
#7	PHONO	LINE TO MOD	.05 (C = 10 μfd)
#17	"	" " "	.05 C =
#18	6J7 GRID	" " "	.05 .5 μfd
#9	PHONO	" " "	.10 (C = 10 μfd)
#10	6J7 GRID (SEE BACK)	500 Ω OUTPUT	.10 (C = 10 μfd)

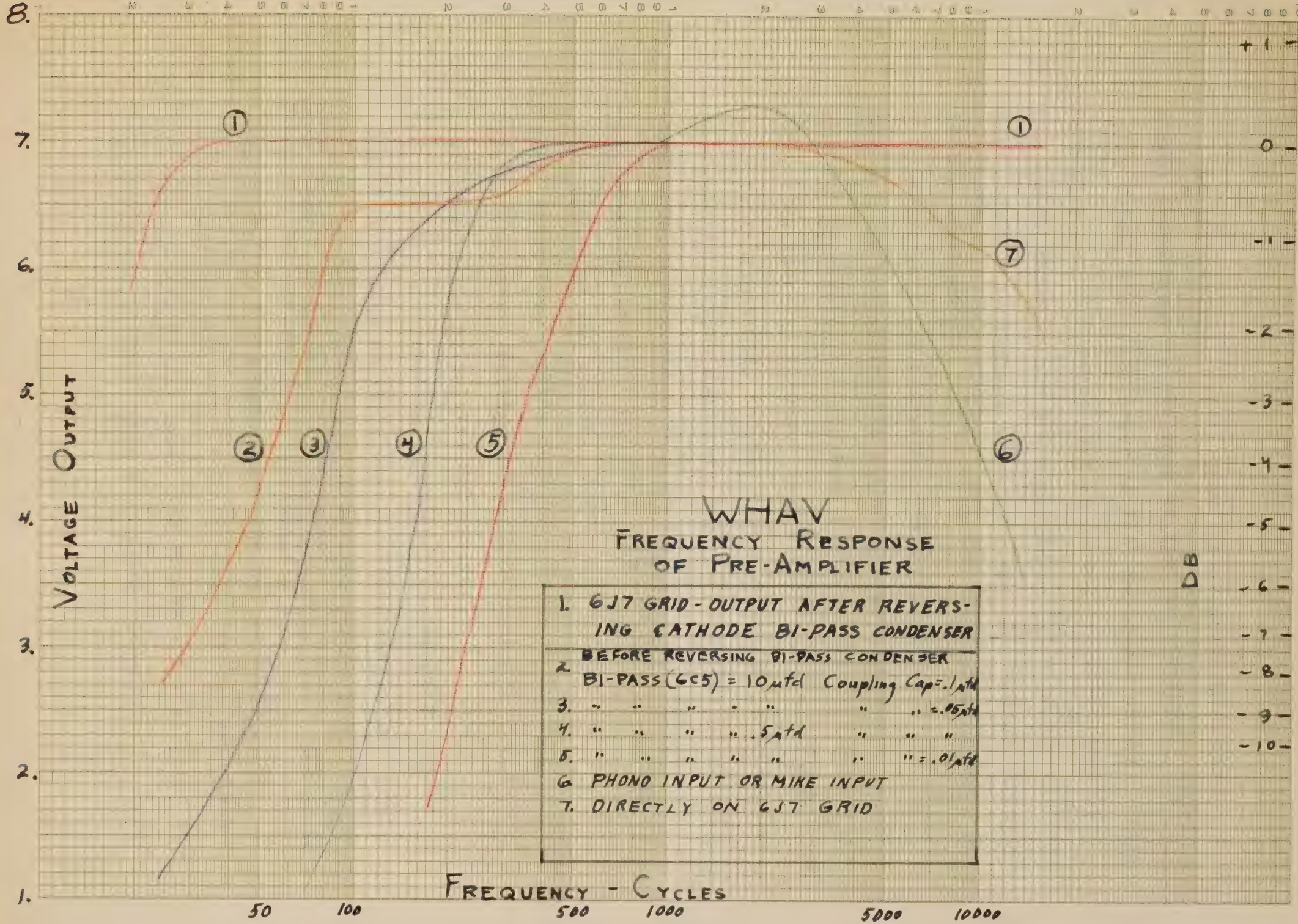
VOLTAGE OUTPUT →

FREQ. - CYCLES →

DB GAIN →


WHAV
FREQUENCY RESPONSE
OF PRE-AMPLIFIER
1. 6J7 GRID - OUTPUT AFTER REVERSING CATHODE BI-PASS CONDENSER
BEFORE REVERSING BI-PASS CONDENSER
2. BI-PASS (CCS) = 10 μfd Coupling Cap = .1 μfd
3. " " " " " " = .05 "
4. " " " .5 μfd " " = .05 "
5. " " " .5 μfd " " = .01 "
6. PHONO INPUT OR MIKE INPUT
7. DIRECTLY ON 6J7 GRID
VOLTAGE OUTPUT
DB
FREQUENCY - CYCLES
50
100
500
1000
5000
10000
+1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
1.
2.
3.
4.
5.
6.
7.
8.

NO. 340-L410 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
EUGENE DIETZGEN CO.


WHAV
FREQUENCY RESPONSE
OF PRE-AMPLIFIER
1. 6J7 GRID - OUTPUT AFTER REVERSING CATHODE BI-PASS CONDENSER
2. BEFORE REVERSING BI-PASS CONDENSER
BI-PASS (6C5) = 10 μfd Coupling Cap = .1 μfd
3. " " " " " " " = .05 μfd
4. " " " " .5 μfd " " "
5. " " " " " " " = .01 μfd
6. PHONO INPUT OR MIKE INPUT
7. DIRECTLY ON 6J7 GRID
VOLTAGE OUTPUT
DB
FREQUENCY - CYCLES
50
100
500
1000
5000
10000
+1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
1.
2.
3.
4.
5.
6.
7.
8.

An interesting fact is that the response thru the output transformer is the same as that to its input. In other words, the transformer is flat to 15,000 cycles. There is indication of a sharp peak at 6-8000 cycles on some of the curves taken to the 500 ohm output. This is the resonant frequency of the leakage inductance and the winding capacity of the transformer.

Concerning low frequency response, a marked improvement was made by increasing the cathode bi-pass condenser on the 6C5 and increasing the coupling condenser to the grid of the 6C5. The tube had been put into the preamp without attention to circuit constants, and the result was poor base response. The cathode bi-pass condenser was .5mfd, across 2500 ohms. With this, degeneration will begin when the reactance of the condenser is about one half the resistance of the cathode resistor. This occurs at 260 cycles. Curves #17 and #18 show this best, since the coupling condenser in these has been corrected. The curves show a falling off beginning at 330 cycles, which is close to the calculated 260 cycles.

As for the coupling condenser, the response may be again calculated as 70.7% when the reactance of the condenser is equal to the equivalent resistance formed by the plate, coupling and grid resistors in Series with in parallel. The plate resistance of the triode connected 6J7 is 10,500 ohms. The coupling resistance is 50,000 ohms, and the grid leak of the 6C5 was 50,000 ohms. The equivalent resistance is thus about 57000 ohms. With a coupling condenser of .01 mfd

the response is thus 70.7% at 280 cycles. No curve was made with this small condenser and proper cathode bi-pass. Curves 1,2,3,4 show the poor bass response that is the combination, and the part of it due to the too small coupling condenser is the difference between these and #18 and 17. Changing from .05 to .10 improved it from #7 to #9. A great improvement was made by increasing the grid resistor from 50000 ohms to 250000 ohms. This was done later and no curve has been taken since the change.

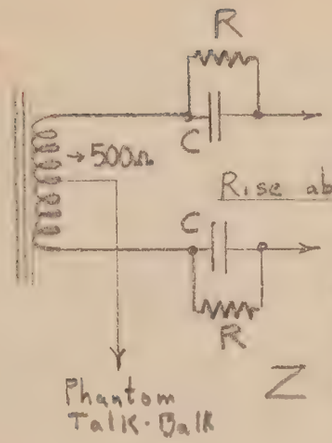
Some of the high frequencies are being lost in the coupling between the 6J7 triode connected andthe 6C5. This is againdue to the shunt capacity of the coupling network. When its reactance is equal to the equivalent resistance formed by the plate, coupling and grid resistors all in parallel, the response is 70.7%. The plate resistance of the 6J7 is low and this falling off is thereby kept to a minimum.

There are several methods by which a falling off may be counterbalanced in the preamp. All that will be mentioned here involve degeneration or attenuation of the frequencies which come thru best. In order to do this, one must have excess gain, which the preamp does not have at present. The voltage gain of the 6J7 could be trebled by changing from triode to pentode connection. The proper screen resistance for this would be .5 meg., the screen bi-pass condenser a .5 mfd. The load resistor should be changed to .1 meg. and the cathode resistor to 450 ohms. The present bi-pass of 10 mfd. is sufficient, as is the present coupling

condenser. The voltage gain would be 80 under these conditions, ~~of which~~ and only eight volts are ~~is~~ needed to drive the 6C5. It would be possible to introduce degeneration in the cathode resistor, and negative feedback. Figure 11 d shows negative feedback, or degeneration, in the cathode by means of a small bi-pass condenser. If this is applied to the 6J7, the value of R may be large to provide more degeneration. To keep the bias the same, the grid resistor must be returned to the cathode resistor so that 450 ohms remain between it and cathode. Thus if one wished to attenuate everything up to the frequency of 3000 cycles, where the response falls off, and then make it rise as much as it fell by 10,000 cycles, reference would be made to the curve. The voltage at 10,000 cycles is 65% of the 1000 cycles voltage. The rise at 10000 should then be 1/.65 or 1.5. Assuming that the condenser will reach complete bi-pass ~~####~~ at 10,000 cycles, and will not be effective below 3000 cycles, one calculates the resistance needed. The loss across the cathode resistance when unbi-passed must be 65% of the total voltage output. Therefore the resistance of the degeneration resistor should be 1/3 of the total plate and cathode resistance, or 50,000 ohms. A condenser of .0015 mfd. would have a reactance of 50000 ohms at 2000 cycles, and 10000 ohms at 10000 cycles. Thus ¼ of the signal would be thrown away at 2000, and 1/8 at 10,000, giving a rise of 12% Since the aim was for 50% increase, recalculations would have to be made to give this additional rise. In this method, the 10mfd condenser must

F-5 II

a.

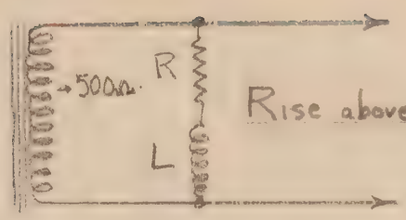


Rise above f_o

$R = \frac{1}{2\pi f_o C}$

Z below $f_o \cong R$

c.

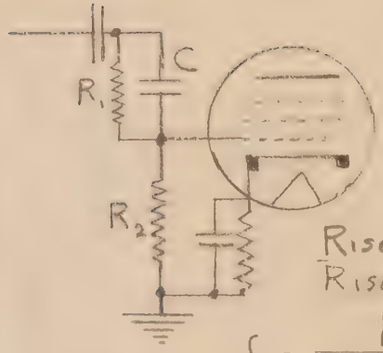


Rise above f_o

$R = 2\pi f_o L$

Z below $f_o \cong R$

e.



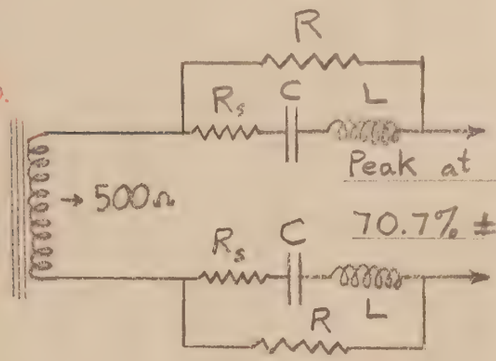
Rise above f_o

Rise to $n v_o$

$f_o = \frac{1}{2\pi C R_1}$

$n = \frac{R_1 + R_2}{R_2}$

b.



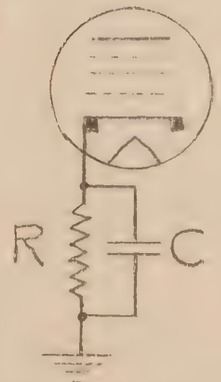
Peak at f_o

$70.7\% \pm \frac{f_o}{2Q}$

$f_o = \frac{1}{2\pi\sqrt{LC}}$ $\quad Z_{f_o} = \frac{R_s R}{R_s + R}$

$Q = \frac{2\pi f_o L}{R_s}$ $\quad Z_{max} \cong R$

d.

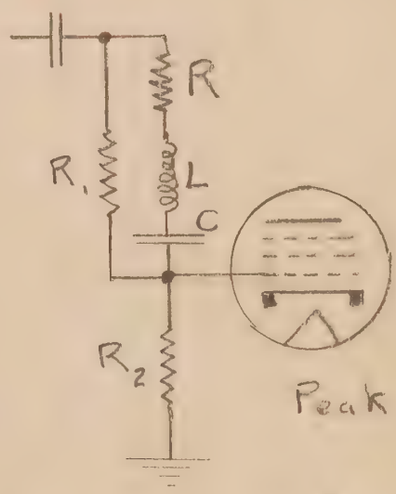


Rise between f_1 & f_2

$f_1 = \frac{1}{2\pi RC}$

$f_2 = 5 f_1$

f.



Peak at f_o

$f_o = \frac{1}{2\pi\sqrt{LC}}$

$Q = \frac{\omega L}{R}$

WHAV

LINE EQUALIZERS

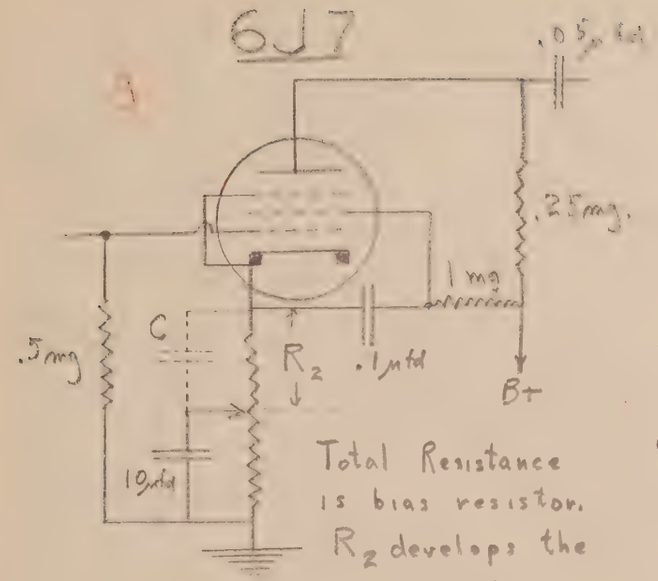
ATTENUATORS AND BOOSTERS FOR BETTER HIGH RESPONSE

remain between the grid return and the cathode to prevent degeneration of the grid voltage.

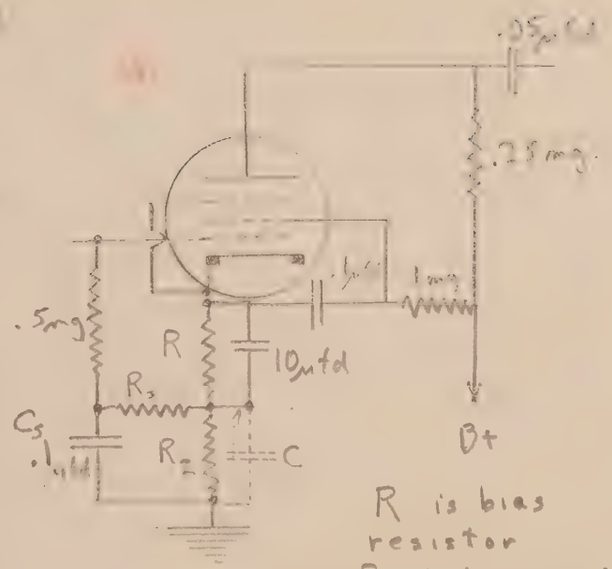
This last statement leads directly to another type of degeneration, that of grid voltage. Whereas the type just described essentially throws away a portion of the output for certain frequencies, grid voltage degeneration throws away input voltages. It has the advantage of decreasing the frequency and the amplitude distortion. It works as follows: if a positive signal is applied to the grid, more plate current flows. If the grid resistor is returned to ground, and the cathode resistor is insufficiently bi-passed, the increased current will cause a greater drop in the cathode resistor. This biases the tube more and cancels out the signal applied to the grid to some extent. When a pentode is used the screen must be supplied with a series resistor bi-passed to the cathode, and the suppressor grid must be connected to the cathode, not ground. The feedback voltages would be applied to these elements also if they were grounded.

Figures 12 g. and h. illustrate grid signal degeneration. The use of one or the other depends on whether the bias resistor is sufficiently large to develop the desired feedback voltage. In both cases the feedback voltage is developed across R_2 and the feedback factor β is $\frac{R_2}{R_{eq}}$ where R_{eq} is the coupling and grid resistors in parallel. By setting up two simultaneous equations in R_2 and X_c the

Fig. 12



Total Resistance is bias resistor.
R_2 develops the feed back
Response begins rise when $\frac{1}{2\pi fC} \cong 2R_2$



R is bias resistor
R_3 holds grid at proper voltage but isolater AC feedback
R_3 = .5 mg.

Low Pass Filter

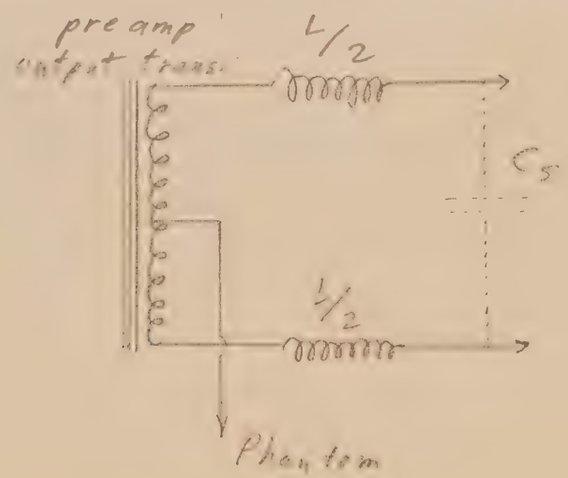
C_s = line shunt capacity

Z must = line impedance

f_0 = highest band frequency

$$Z = \sqrt{\frac{L}{C_s}}$$

$$f_0 = \frac{1}{\pi\sqrt{LC_s}}$$



WHAV

DEGENERATION AND NEGATIVE FEEDBACK

proper values may be determined to give a response flat up to 2000 cycles, then rising to 1.5 times this at 10000 cycles. Since the amplification with feedback is given with good accuracy by the equation

$$\text{Ampli.} = \frac{A}{1 - A\beta}$$

A = voltage amplification without feedback

β = feedback factor = R_2/R_{eq}

R_2 is made to decrease with increaing frequency by a suitable condenser, lowering the feedback and raising the amplification. Circuit h would be needed with the 6J7; with R_2 = 2000 ohms and C_2 = .04 mfd. the amplification up to 2000 cycles would be 37, and from 2000 to 10000 would rise to 58, 50% rise. R_B is an isolating resistor with condenser C_3, to put the grid at the proper bias but not ground the feedback voltage.

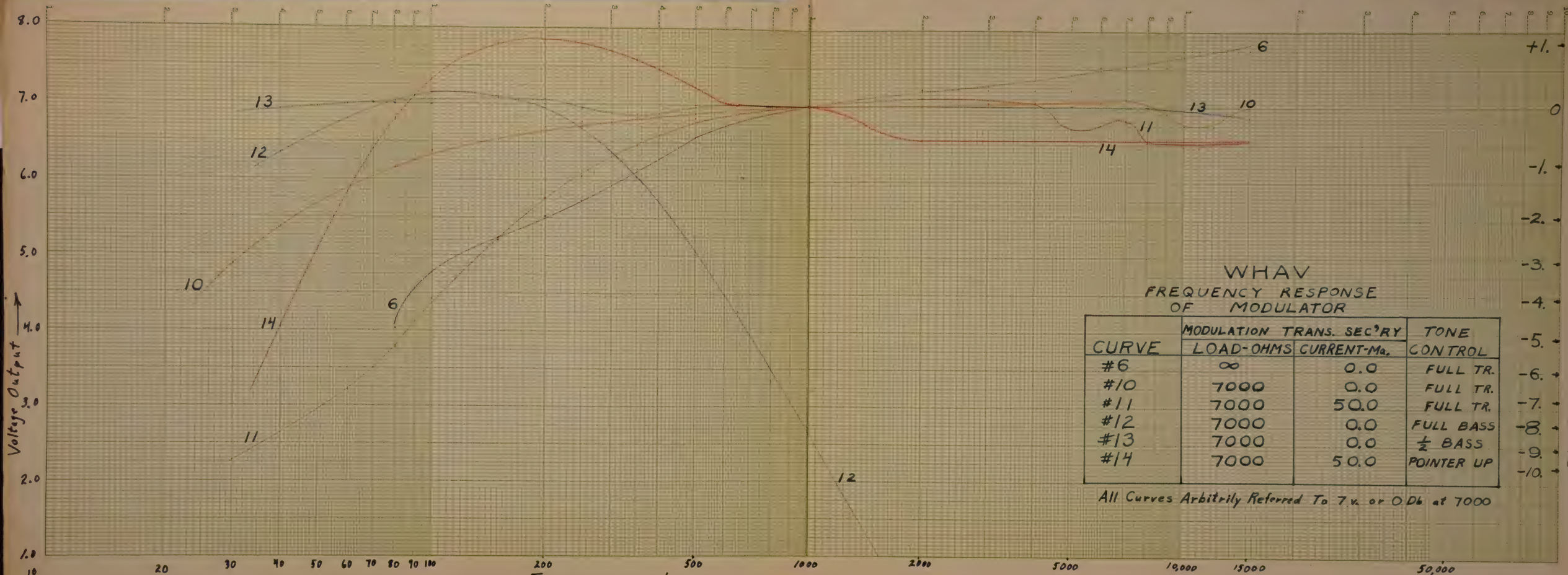
Circuits such as e. and f. will do the same thing to the frequency response if properly designed, but don't offer the improvement in frequency distortion that g. and h. do.

The frequency response of the modulator was next tested. The curves make it evident that no trouble was or is to be expected in high frequency response. These curves are all with the Stancor Modulation Transformer. The bass response changes with load resistance and current enough to make it necessary to equalize it. Curve #11 represents the way in which the modulator had been operated. The response is down 4 db at 100 cycles and 10 db at 30 cycles. This falling off is due in part to saturation of the transformer core by the secondary durrent, and partly to low frequency falling off of the transformer with no secondary durrent.

The tone control on this amplifier is a .01 mfd condenser

KEUFFEL & ESSER CO., N.Y. NO. 358-63
Semi-Logarithmic, 2 Cycles × 20 to the inch.
MADE IN U.S.A.

Severinghaus, J.W.
March 18, 1943



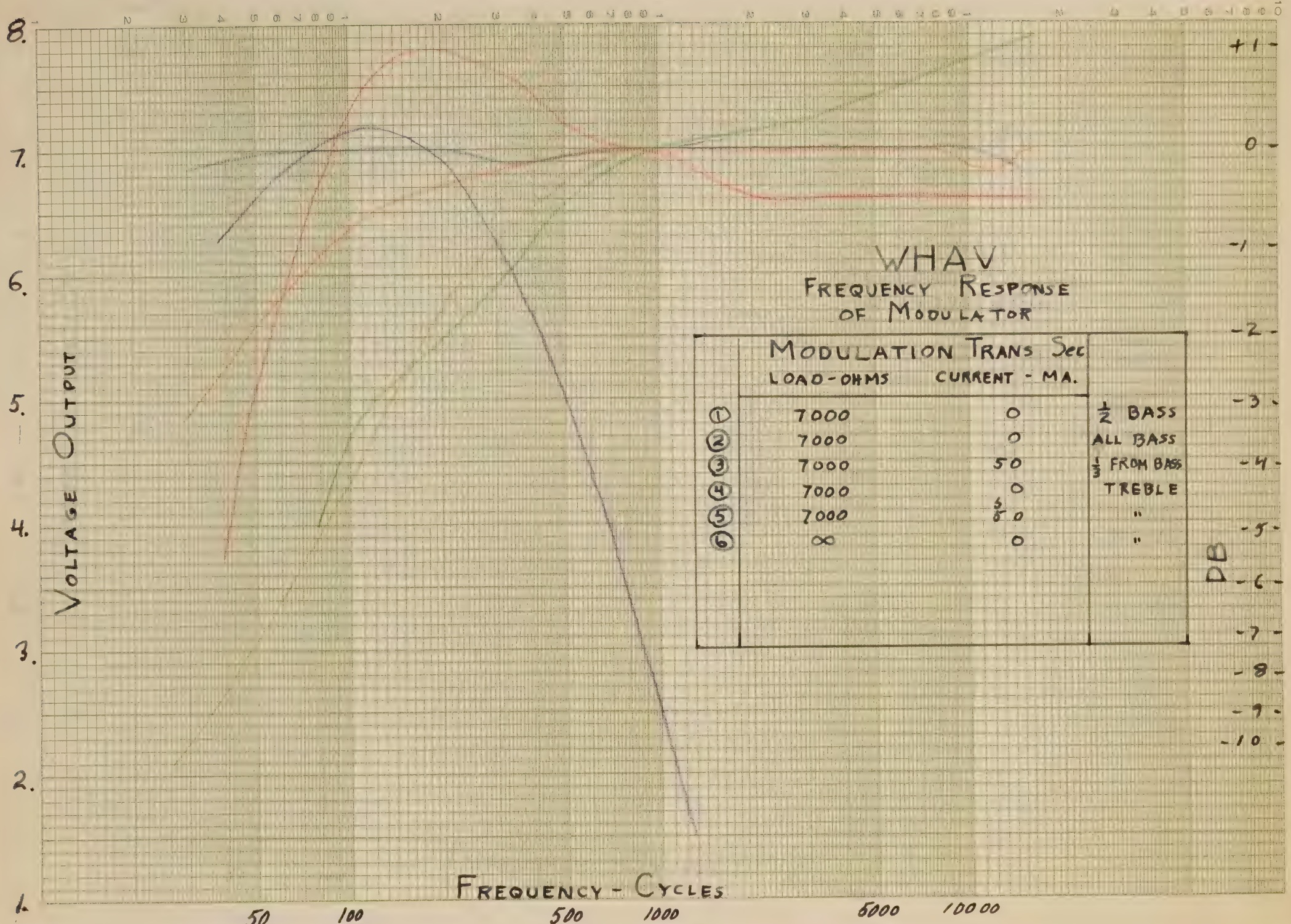
WHAV

FREQUENCY RESPONSE OF MODULATOR

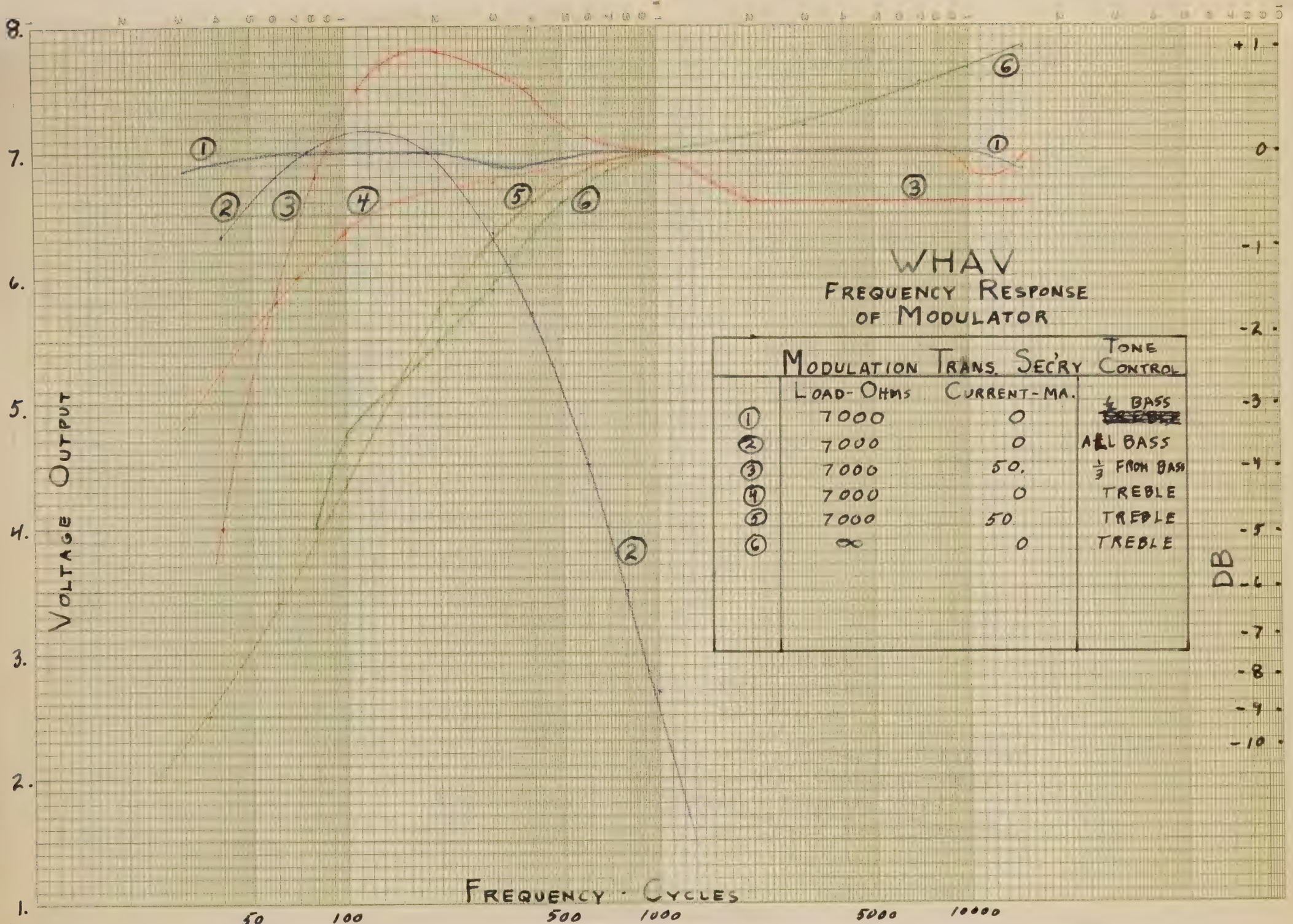
CURVE	MODULATION TRANS. SEC'RY LOAD-OHMS	MODULATION TRANS. SEC'RY CURRENT-Ma.	TONE CONTROL
#6	∞	0.0	FULL TR.
#10	7000	0.0	FULL TR.
#11	7000	50.0	FULL TR.
#12	7000	0.0	FULL BASS
#13	7000	0.0	½ BASS
#14	7000	50.0	POINTER UP

All Curves Arbitrily Referred To 7 v. or 0 Db at 7000

Sereringhaus 3/18/43



SEVERINGHAUS 3/18/43



WHAV

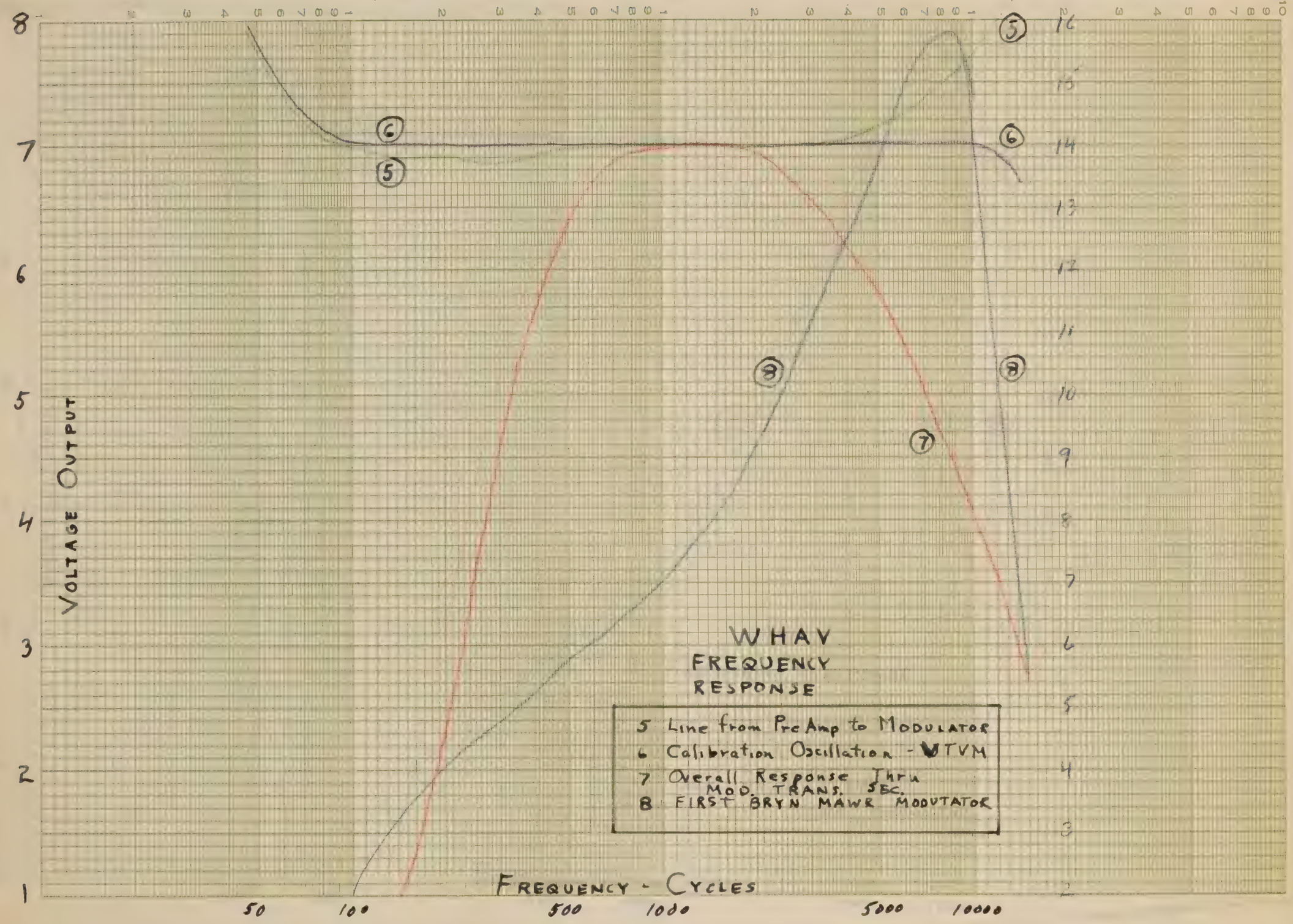
FREQUENCY RESPONSE OF MODULATOR

	MODULATION TRANS. SEC'RY LOAD-OHMS	CURRENT-MA.	TONE CONTROL
①	7000	0	½ BASS
②	7000	0	ALL BASS
③	7000	50.	⅓ FROM BASS
④	7000	0	TREBLE
⑤	7000	50	TREBLE
⑥	∞	0	TREBLE

NO. 340-L410 DIETZGEN UNAR
SEMI-LOGARITHMIC
1 CYCLE X 10 DIVISIONS PER INCH

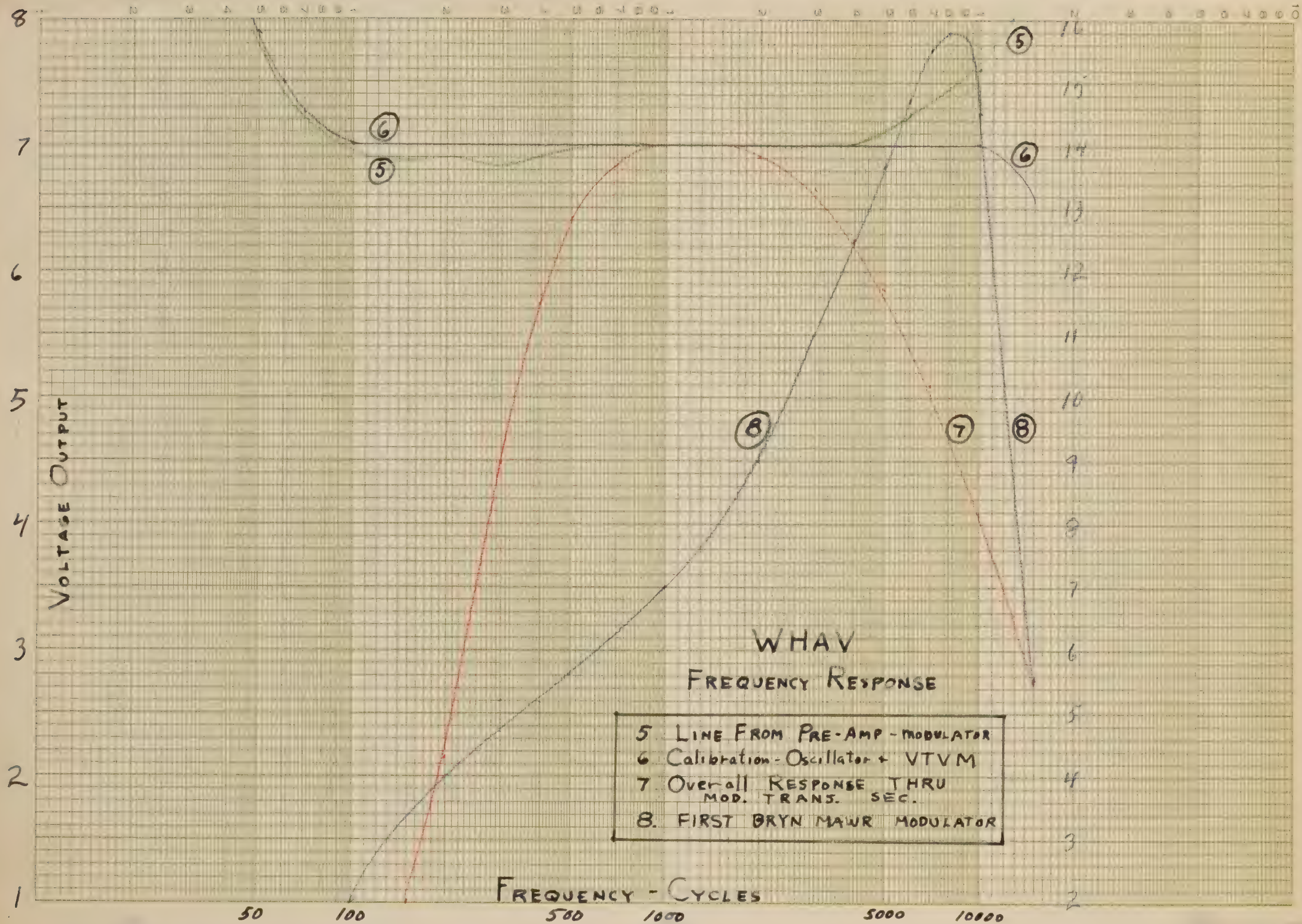
EUGENE DIETZGEN CO.

Severinghaus 3/18/43



NO. 340-L410 DIETZGEN GRAPH-APL
SEMI-LOGARITHMIC
EUGENE DIETZGEN CO.

Sevringhaus 3/18/43



NU 340 L410 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
4 CYCLES X 10 DIVISIONS

EUGENE DIETZGEN CO.

and a potentiometer used as the plate resistance of the amplifier section of the 6SC7. Its action is to act as a partial short circuit to all frequencies above the frequency at which the part of the potentiometer above the tap has resistance equal to the reactance of the condenser. If the amplifier has enough gain, then, it acts as a bass booster. This is just what is needed to compensate for the bass loss in the modulator. Curve 14 is the setting found most satisfactory with the operating conditions. This is flat within 1½ db from 65 to 15,000 cycles. This position of the tone control is used now. The response may be calculated from curve # 12 for any value of resistance between the plate and the condenser and the tube. The curve will tend to level off above the frequency at which the reactance of the condenser is equal to the resistance.

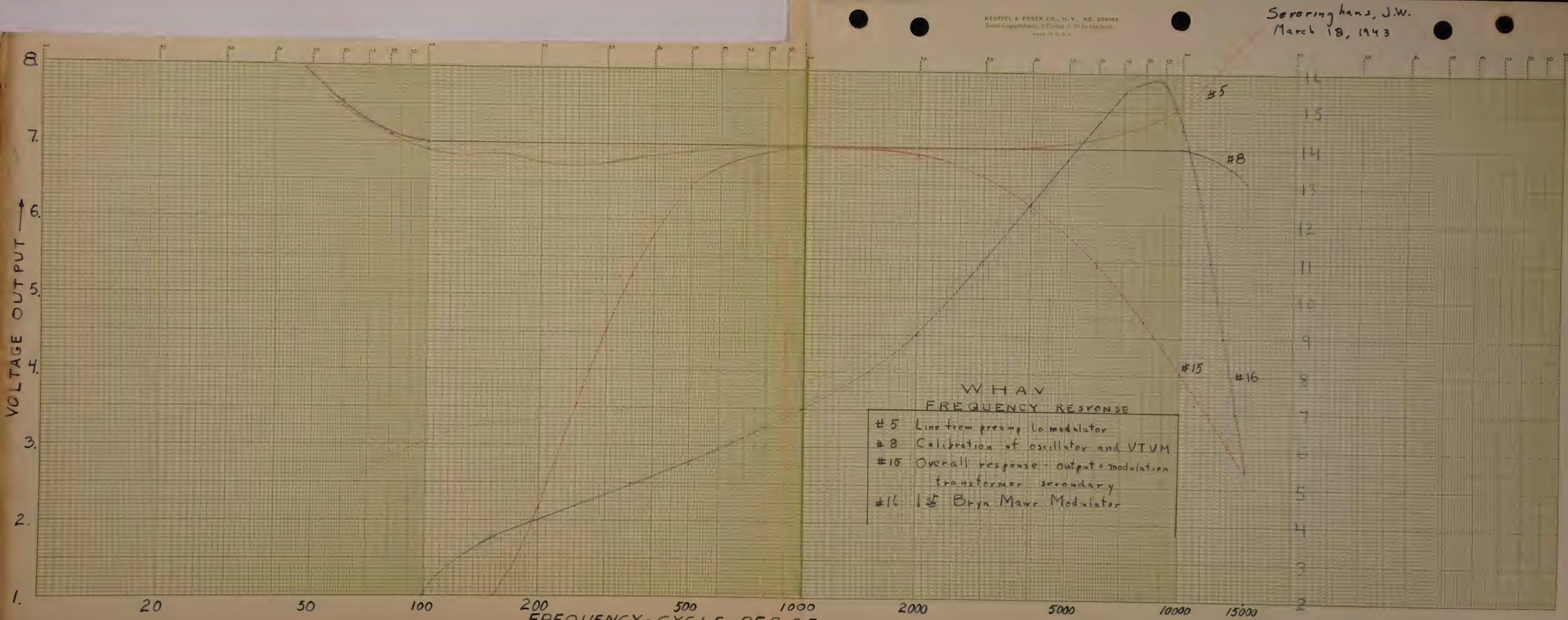
The initial overall response shown is shockingly poor. There remain several curves to be studied. One is the response of the transmitter. The plate and screen bi-pass condensers may be too large. The response of the phone line to Bryn Mawr is known only from curves found in the literature of the Bell Telephone Company. These indicate an attenuation of about 8 db is to be expected between Haverford And Bryn Mawr for 1000 cycles. The curve of attenuation rises rapidly.

An attempt to measure the open and short-circuited impedances of the line was made. These were difficult to determine with accuracy; however the capacity of the line was measured as # .3mfd. Its AC resistance is 450 ohms per side. To counteract this shunting capacity and attenuate

Note: Curve #5 is not significant, since the input to the line was the 500 Ω output of the oscillator. It should have been fed thru the 6C5, keeping constant voltage on output. This is feeding a 500 000 Ω grid, and the capacity shunting would attenuate at a lower frequency.

KEUFFEL & ESSER CO., N. Y. NO. 358-93
Semi-Logarithmic, 2 Cycles × 20 to the Inch.
MADE IN U. S. A.

Severinghaus, J.W.
March 18, 1943



the lows instead of the highs, the circuit shown in Fig. 11 a is employed. The impedance to frequencies below F_o is nearly R. This decreases continuously above f_o as the reactance of the condenser decreases. The circuit used employs .1mfd condensers and 200 ohm resistors. This does not rise sufficiently to equalize the line, and should be changed to .4 mfd with 200 ohms. The response curve should be measured both with and without the equalizer.

Other methods of line equalization are shown in b. and c. Fig 11 B. will give a peak at the resonant frequency where the attenuation falls below normal response by a factor of $\frac{R_s}{R+R_s}$.

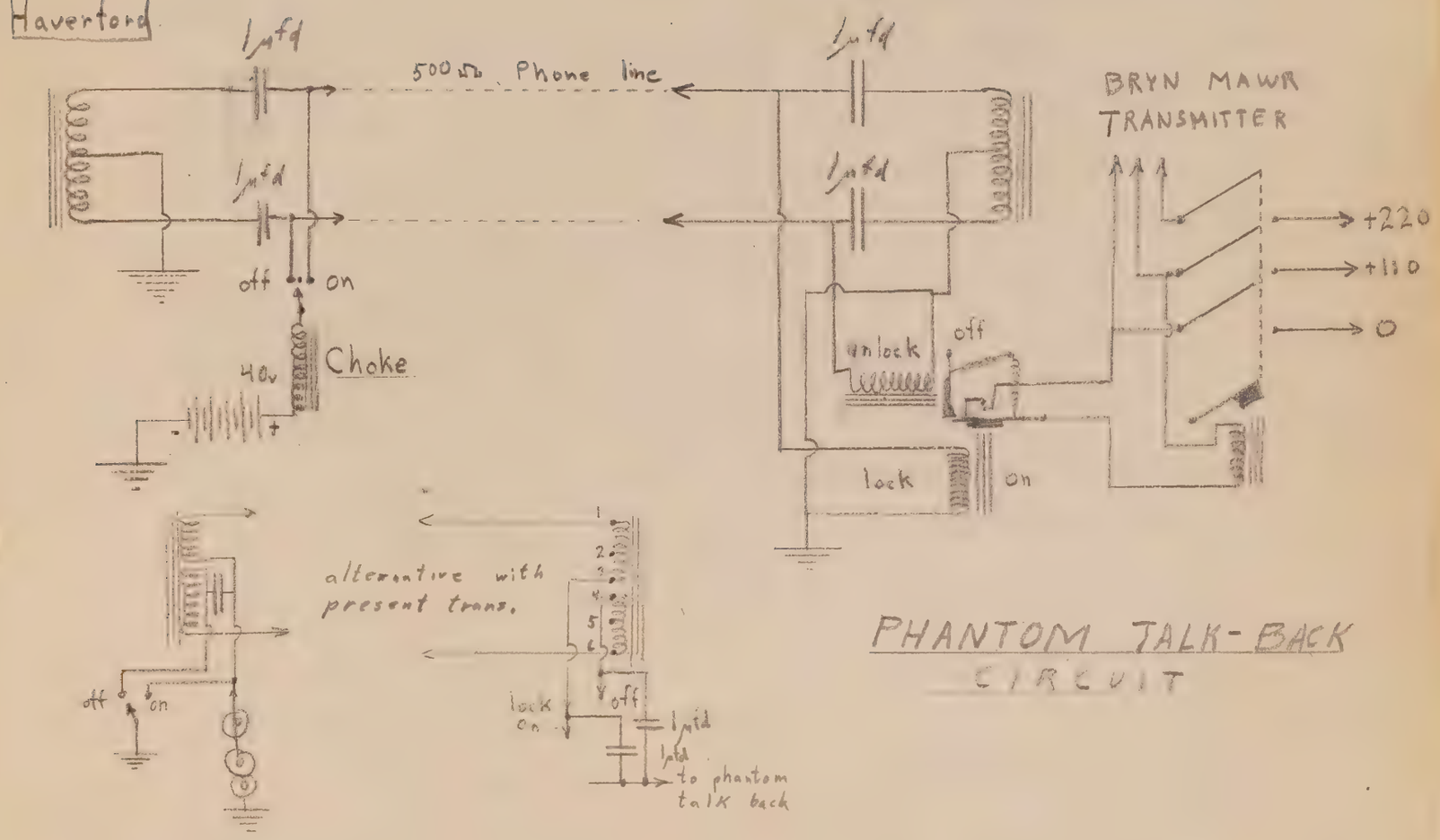
Circuit 11 c. will have a rising characteristic above the frequency at which $2\pi fL = R$. Suitable values for the Bryn Mawr Phone line would be R = 100 ohms, L = 8 mhy. Both of these circuits will affect the terminating impedance of the line, but if the values are wisely chosen, no echo effects should occur, and balance may be maintained.

The signals being sent to Bryn Mawr travel out of phase down the line. That is, the current is in opposite directions in the two sides of the line. Since the matching transformers at bothends are centertapped, another use may be put to the line. Any current which travels down the line in the same direction on both sides will cancel magnetic fields in the transformer at the Bryn Mawr end, and none will be effective in producing a signal on the modulator. This is true only if the transformer is well balanced. Therefore, a carbon microphone and reciever may be placed between the center tap

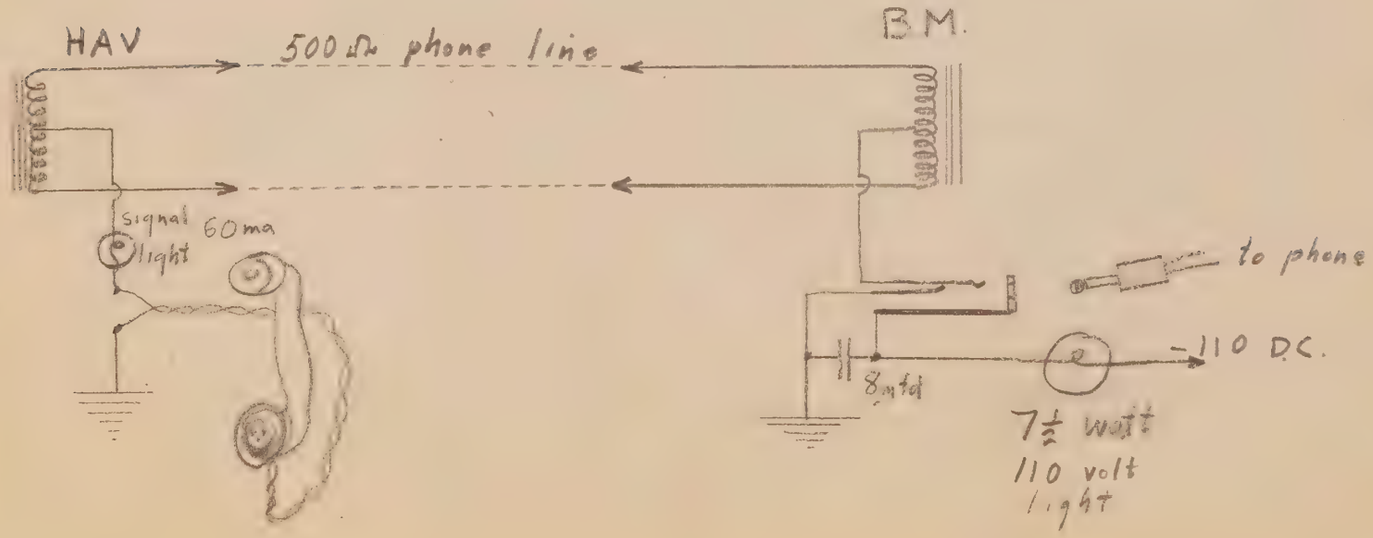
Fig 15

WHAV

REMOTE CONTROL FOR BRYN MAWR TRANSMITTER



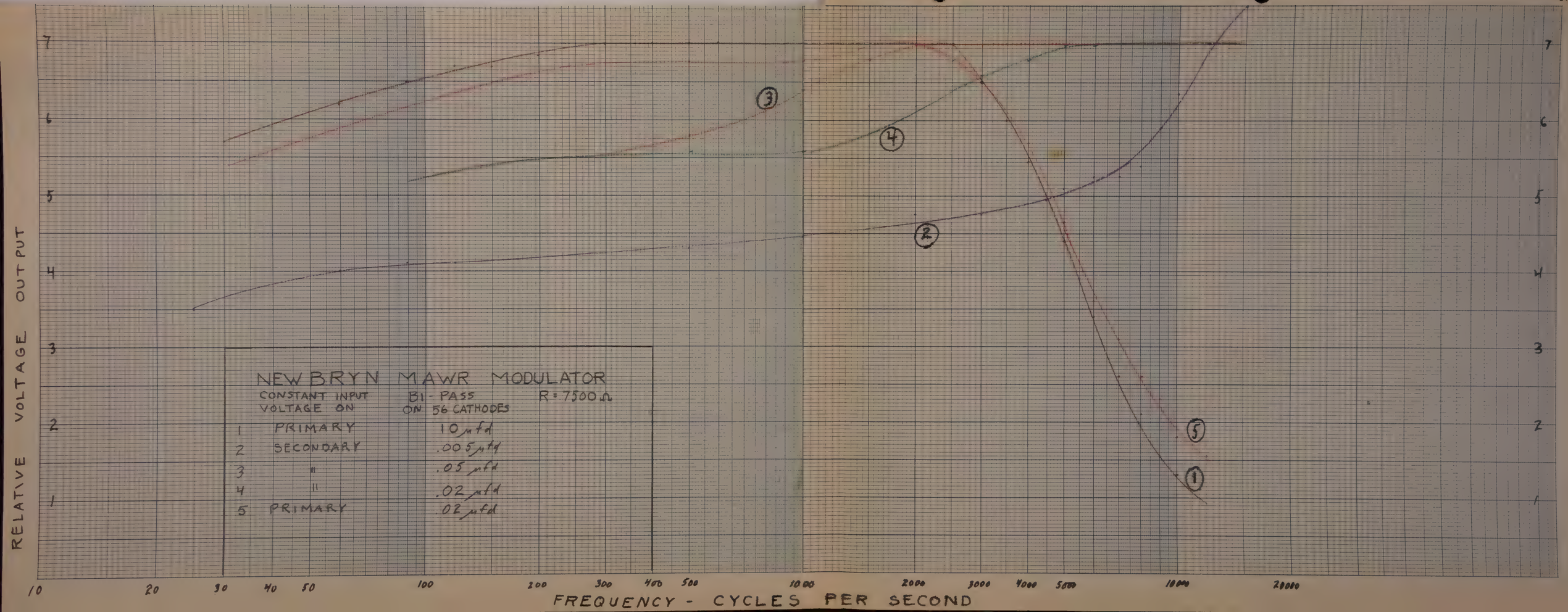
PHANTOM TALK-BACK CIRCUIT



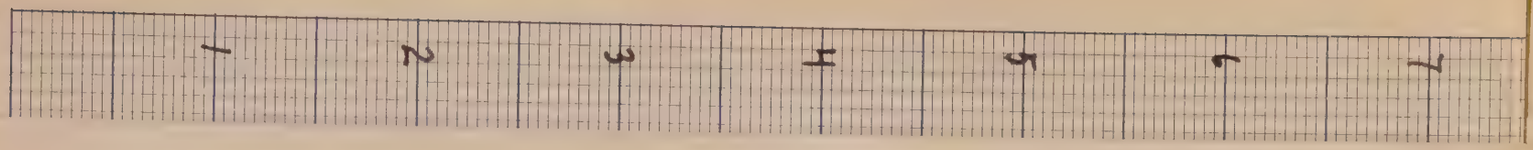
and ground at both ends, with a battery to give button current. This may be used for an engineer's talk-back while the program is on the air. Figure 15 shows the circuit used andthe method of obtaining DC from the Bryn Mawr power lines. Since the entire system of DC at Bryn Mawr is floating with respect to ground, the exact difference of potential between the negative lead and ground varies from hour to hour. The possibility exists that the -110 volt line might become positive with respect to ground, and thus ruin the 8 mfd condenser which is used to filter the ripple in the DC sourse. The 7½ watt lamp in the supply is used as a 1500 ohm resistor, giving 50 ma. button current with 110 volts between line and ground. This circuit is known as a phantom talk-back and is commonly used. The Bell System uses phantom circuits between the center taps of two adjacent pairs as a regular additional pair. For n pairs of wire n - 1 phantom circuits may be had, provided n is an even integer.

The phone line was used for one additional purpose. The transmitter at Bryn Mawr is controlled by an Electron Coupled Oscillator. The frequency of this was set by feeding the RF signal into the line thru a link coupling and small condenser. At Haverford the line was connected to antenna and ground posts of the RME. With the beat frequency oscillator set to read 610 at zero beat with WIP, the dial was set for 640 Kc. Using the phantom circuit to listen, the engineer at Bryn Mawr tunéd the oscillator until the squeal was heard

001 Severinghaus 4/13/43 01



RELATIVE VOLTAGE OUTPUT



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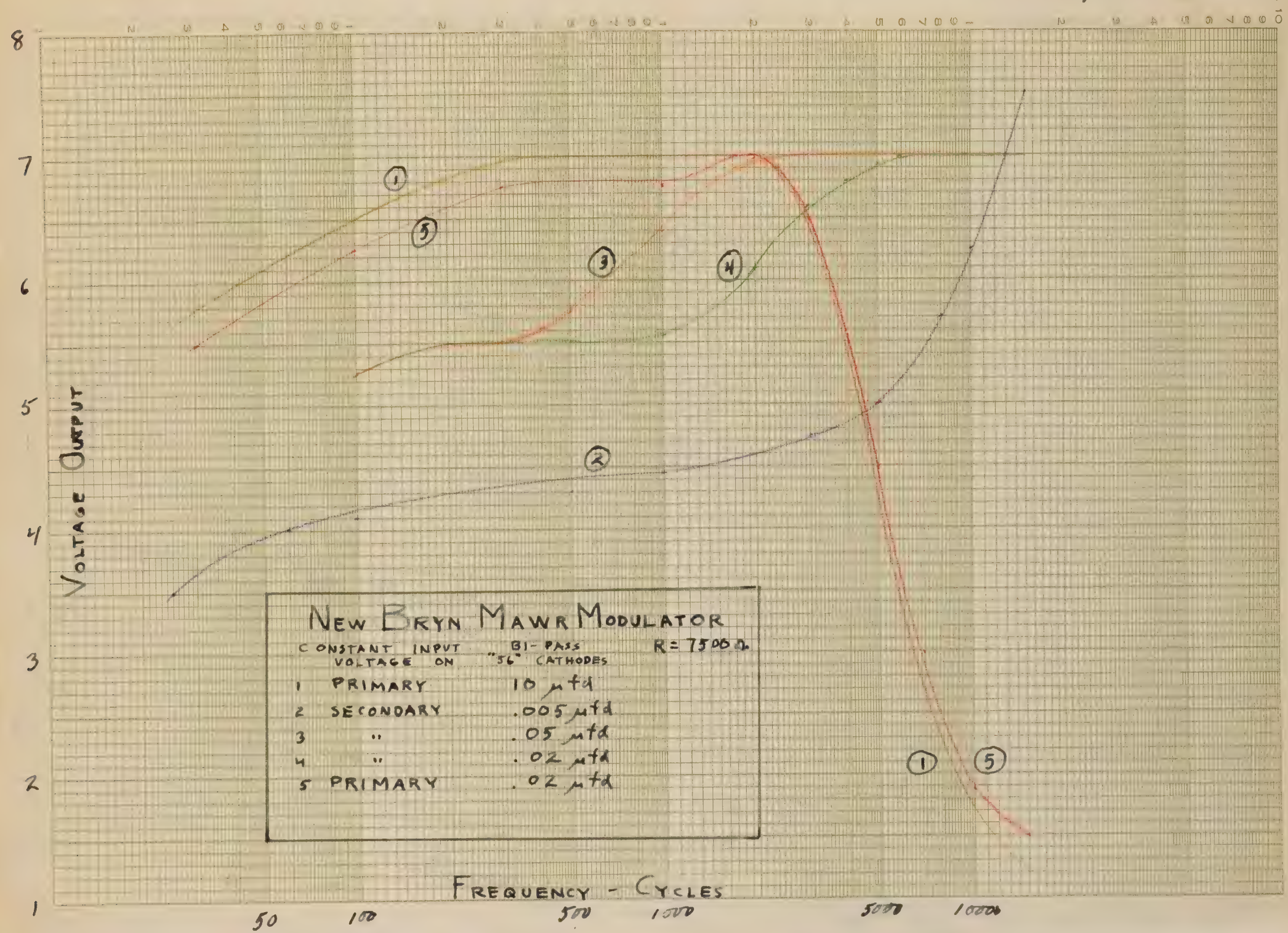
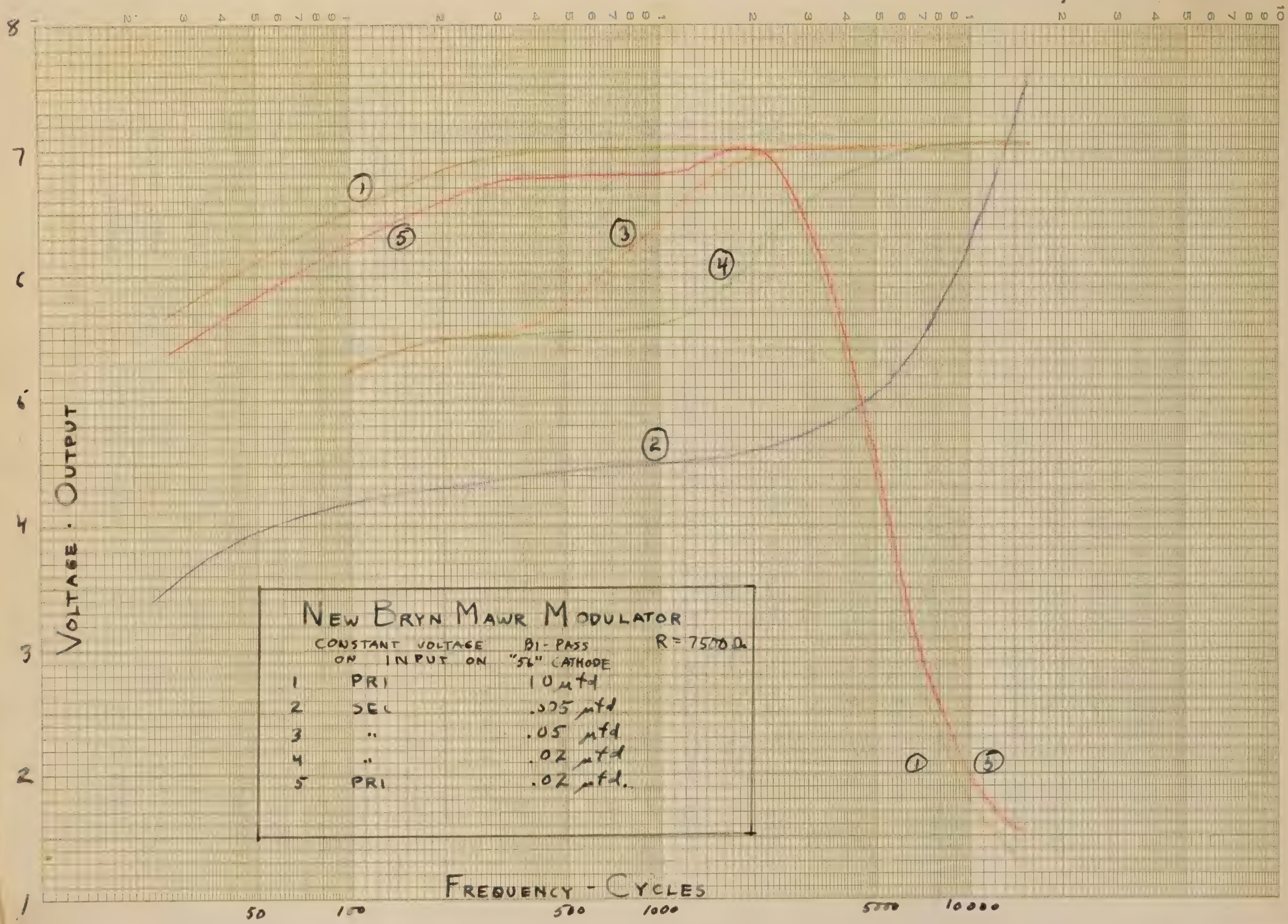


Severinghaus 4/18/43



NO. 340-L410 DIETZGEN GRAPH PAPER

on the phone. Tuning to zero beat set the transmitter at 640 Kc. With a capacity of .3 mfd across the line, it is obvious that the attenuation of the 640 Kc. signal must have been great. The line is about 3 miles long, and it was with some surprise that this was found to carry sufficiently to hear on the RME.

The frequency response of the original Bryn Mawr ~~Transmitter~~ Modulator is plotted on curve #16. Fig 14 This shows a peak in the input transformer at 9000 cycles. The modulator was at that time merely a transformer driving a single 6L6 from the line. This was found entirely too small to modulate the transmitter. The new modulator with a new line to grid transformer gives a response curve as shown in graph IV. Fig 16 The entire secondary winding, which is meant to be push-pull grid, is used for the the 56 amplifier. The attenuation at the high frequencies may be decreased by using only ½ of the winding, since the two grid windings are on the outside and would have fairly large inter-winding capacity. July May 10 The other half should be fed to a resistance equal to the potentiometer across the grid to ground. It may be seen from the curves with constant input to the secondary of the transformer, that the response of the modulator thru the modulation transformer is constant up to 15,000 cycles and falls off only a little down to 30 cycles. This was without secondary current in the transformer.

A cathode ray oscilloscope may be used in place of a vacuum tube voltmeter to measure frequency characteristics. The response of the CRO amplifier is usually flat to 20000 cycles, and its sensitivity may be calibrated for different

USE OF CATHODE RAY 'SCOPE TO DETECT DISTORTION

INPUT ON HORIZONTAL

OUTPUT ON VERTICAL

UNDISTORTED

PHASE SHIFT

FREQUENCY DISTORTION

PHASE SHIFT WITH FREQ. DISTORTION

settings ofthe amplifier gain control. A typical CRO such as the Engineering lab. owns, is calibrated by use of an accurate 60 cycle AC voltmeter and potentiometer or Variac. If the unknown input is applied to the horizontal plates and the output to the vertical plates, this provides an excellent method of keeping the input constant. The method is as follows:

Determine the maximum response of the network in question, that is the frequency at which amplification ## is greatest, without distortion, by swinging the oscillator dial across the frequency range in question. Phase distortion and change produce and change an elipse when the input and output are fed to the two sets of plates. ~~Frequency~~ Amplitude distortion is shown by a curvature of the line or elipse at the ends as shown on the opposite page. This is due to driving a grid positive or beyond cutoff (operation in the curved portion of the curve near cutoff will give some distortion).

Set the CRO input and output gain controls to give a deflection covering nearly the whole screen at this point. Do not change the input ###### CRO gain control after this. The output may be measured with a ruler for each frequency after the Audio oacillator output is set to give the standard deflection on the horizontal plates. If the signals are of low voltage, turning off the vertical amplifier while measuring the horizontal deflection will help; same for vertical.

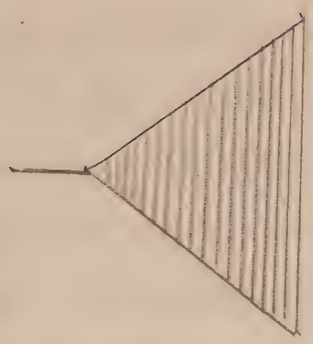
Knowing how to calibrate an audio oscillator to read accurately any frequency is an art. Many tricks were learned while these curves were being made and some of them will be passed on. The

dial of the oscillator does not read correctly for all freq. if set right at one, no matter whether it is warmed up or not.* To start with be lower end of the band, calibration at 30 cycles is accomplished by listening to the hum of a transformer, and tuning to the 2nd harmonic below it. If it is not impossible to change the setting of the output on the oscillator, it may be calibrated for 60 cycles when the gain is up, using the neon tube on the front. Then tune to the octave below. Earphones across the output must be used for all calibration work. 90 cycles is a perfect fifth above 60(bears the same relation that G does to C below it) Since a 440 cycle tuning fork is usually available, this allows calibration at 110 cycles, as the second octave below. 120 may be set via hum. 150 is a major third above 120, (same relation as E to C below) and 180 is again a fifth. 220 cycles may be set as the first subharmonic of the 440 fork. 330 is a fourth below the fork, (like G to C above.) Above 550, which is again a third above the fork, the dial of the oscillator does not shift much. The harmonics of the fork may be picked up at 880 and 1760, possibly at 3520. The dial will be quite accurate above these frequencies, which is fortunate, since they would have to be set with beat notes. If no 440 fork is available, WWV may be found on the radio at exactly 5 megacycles, and it puts out a 440 cycles note constantly.

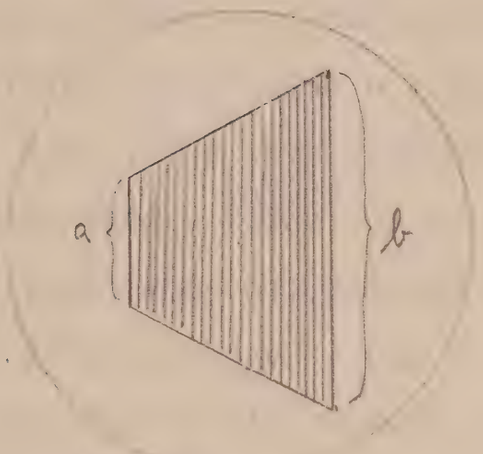
The CRO may also be used to observe wave form with the sweep circuit in the CRO providing a linear time axis.

* It is suspected that the pointer has become shifed.

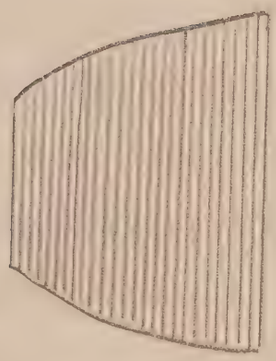
100% Modulation



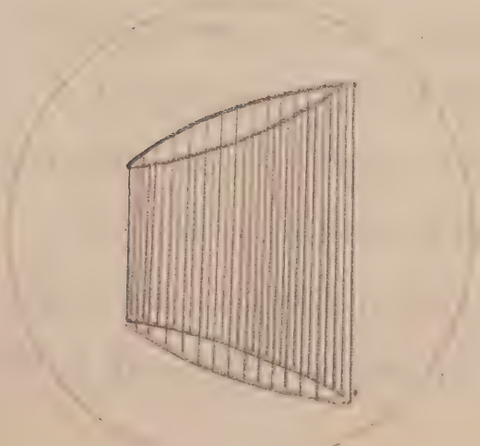
Over modulation



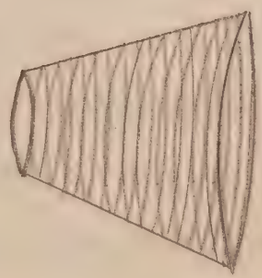
$\frac{b-a}{b+a} \times 100\%$ modulation



amplitude distortion
(non linear Class C response)



phase shift in transmitter



detuned plate or antenna

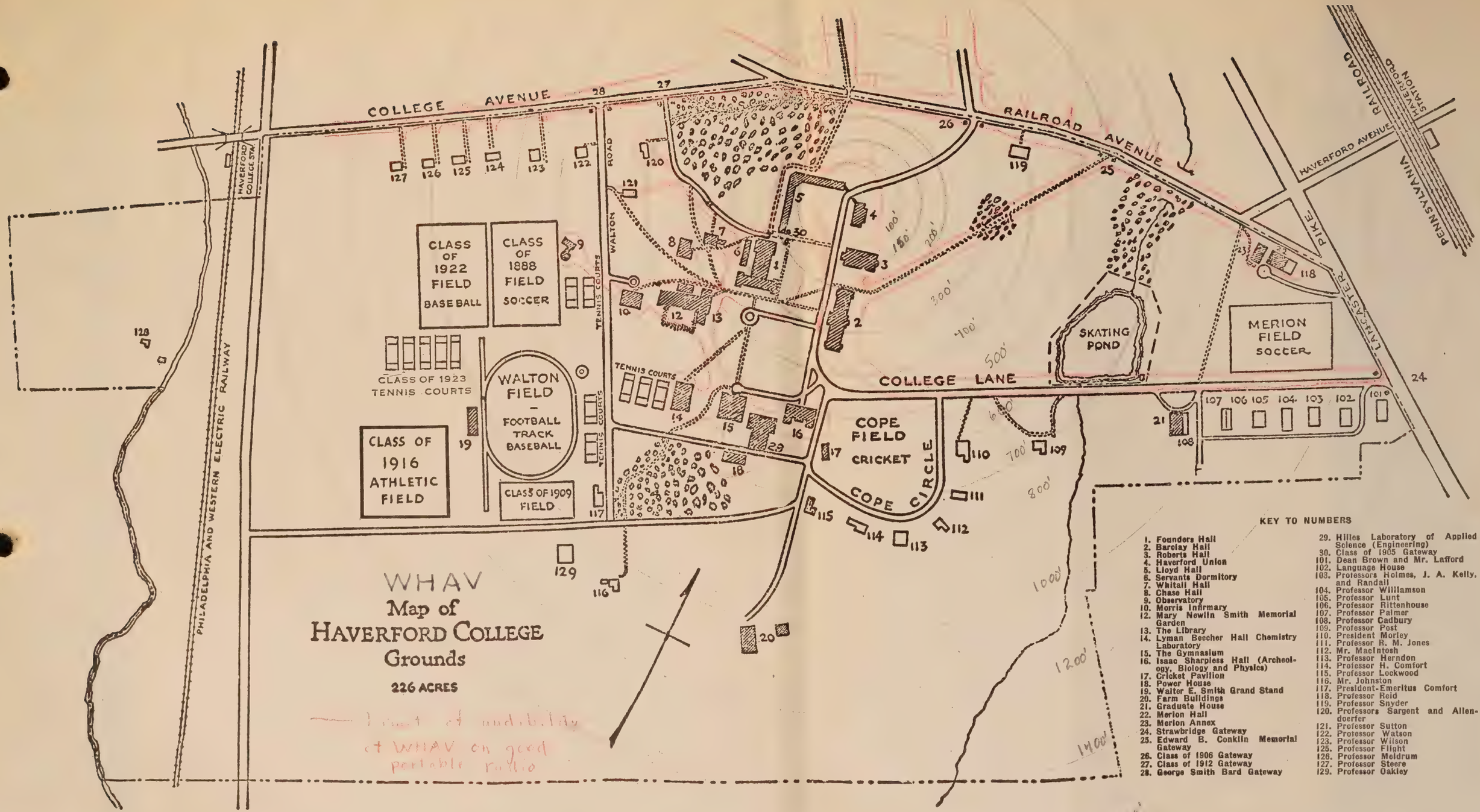
The frequency response of the transmitter itself should be measured for a constant voltage across the secondary of the modulation transformer. This may be done well with the CRO, input on the horizontal plates, RF on the vertical. The trapezoid pattern, ~~to be discussed under the section on monitoring~~, can be used to measure % modulation by measuring the two vertical ends. If the shorter is "a" and the longer "b" then % modulation is: $\frac{b-a}{b+a} \times 100\ \%$

The graph of % modulation vs. frequency is then plotted.

Field Strength Measurements.

Essentially the only restrictions imposed upon carrier current stations by the FCC concern the amount of radiation. The ruling states that the signal level must be no greater than 15 micro-volts per meter where the induction field is as strong as the radiation field. (the induction field is specifically prohibited ~~as a means of transmitting intelligence~~ for broadcasting) This distance is $\frac{\lambda}{2\pi}$ where λ is the wave length of the signal in whatever units are used to measure the distance. In feet, this distance is $\frac{157,000,000}{\text{freq.}}$. For WHAV at 580 Kc. the limit of radiation is thus 270 feet. The distance is to be measured from the radiating antenna, which may be construed to mean all RF lines feeding the signal to buildings which are to redieve the signal.

The construction of an apparatus which can read in micro-



KEY TO NUMBERS

1. Founders Hall
2. Barclay Hall
3. Roberts Hall
4. Haverford Union
5. Lloyd Hall
6. Servants Dormitory
7. Whitall Hall
8. Chase Hall
9. Observatory
10. Morris Infirmary
12. Mary Newlin Smith Memorial Garden
13. The Library
14. Lyman Beecher Hall Chemistry Laboratory
15. The Gymnasium
16. Isaac Sharpless Hall (Archeology, Biology and Physics)
17. Cricket Pavilion
18. Power House
19. Walter E. Smith Grand Stand
20. Farm Buildings
21. Graduate House
22. Merion Hall
23. Merion Annex
24. Strawbridge Gateway
25. Edward B. Conklin Memorial Gateway
26. Class of 1906 Gateway
27. Class of 1912 Gateway
28. George Smith Bard Gateway
29. Hilles Laboratory of Applied Science (Engineering)
30. Class of 1905 Gateway
101. Dean Brown and Mr. Lafford
102. Language House
103. Professors Holmes, J. A. Kelly, and Randall
104. Professor Williamson
105. Professor Lunt
106. Professor Rittenhouse
107. Professor Palmer
108. Professor Cadbury
109. Professor Post
110. President Morley
111. Professor R. M. Jones
112. Mr. MacIntosh
113. Professor Herndon
114. Professor H. Comfort
115. Professor Lockwood
116. Mr. Johnston
117. President-Emeritus Comfort
118. Professor Reid
119. Professor Snyder
120. Professors Sargent and Allendoerfer
121. Professor Sutton
122. Professor Watson
123. Professor Wilson
125. Professor Flight
126. Professor Meidrum
127. Professor Steere
129. Professor Oakley

volts per meter would be quite difficult and lengthy. It would not prove itself usefull to justify its construction. Consequently some means of getting and recording an idea of the strength of signals is needed. It is known that for good rural reception a field strength of 100 microvolts per meter is needed. An estimate would seem to indicate that a strength of 50 microvolts could be detected on good days sufficiently to understand. Therefore, by taking a portable radio around the campus and off campus, the signal strength may be roughly plotted. On the graph with circular coordinate paper, fig 17 the red line represents the limit of reception with vague understandability. This graph is partly hypothetical since it is known that reception is possible near telephone and power lines much farther than shown. These lines seem to pick up the radiation on the campus and carry it for some distance. Thus, the signal was recieved near a power line in front of the Food Fair in Bryn Mawr, but nowhere between there and Panmure Road. Reception is quite possible on College Ave. but rather impossible in the homes on College Lane. Telephone lines account for this.

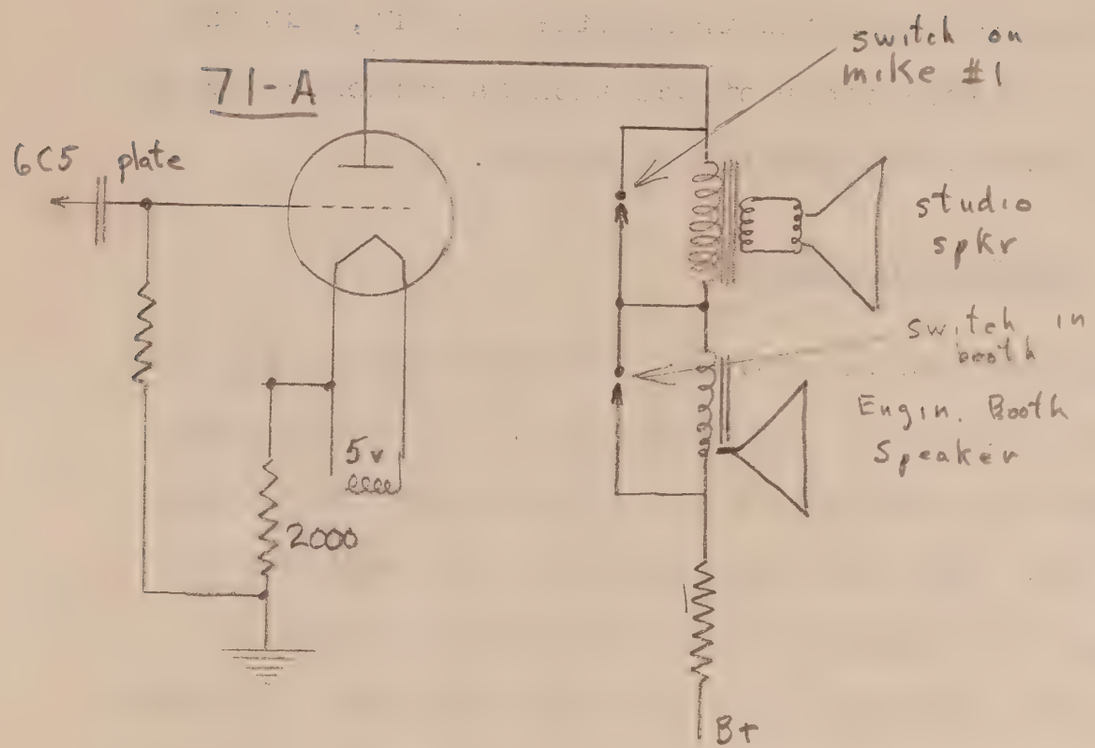
In order to make reception in Merion Hall and Annex possible, RF feeders would have to be run from the walk lights to Merion and tapped into the power wires thru a condenser. An RF feeder from the College lane lights to the power wires behind the homes in "Faculty Row" might make reception possible there.

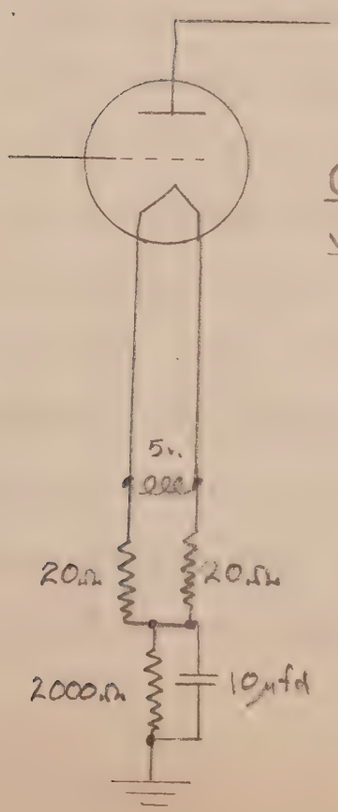
Reception in Barclay, Lloyd and Founders is completely satisfactory, except that the signal is so strong in Lloyd that the second harmonic blocks out WCAU on some radios. It is also believed that there is a parasitic oscillation in the crystal at about 640 Kc, very erratic in nature. No beat note is found on 640 when the transmitter is off, but this one may be due to some other effect such as harmonics of the RME and WHAV oscillators beating at 465 Kc.

Monitor Equipment

Means must always be provided for the engineer to hear the signal as it is going out on the air. He should also be able to hear the out put of the mixer or preamp without broadcasting it. The first provision for the engineer of WHAV was a pair of earphones on the output transformer of the preamp. The RME stood on a table just outside the booth and sinde there was at that time no door on the booth, the engineer could listen to it when music was being played. The volume in the earphones proved too low for decent monitoring, so he 6C5 was added. Turning on and off the RME in the studio was too often forgotten when speech was to go on - result: feedback and a break while the RME got turned off. When the transmitter was moved to the next room, the RME was moved into the booth. It had to be monitored with earphones still, but would provide ample volume, and could be controlled by the engineer, an advantage especially when trying to get BBC for rebroadcasts. The RME was the only method for testing

Circuit of studio amp.





Cut hum and increase volume like this

for distortion in the signal and had to be used frequently for that. The distortion arose, not from over-modulation but from overdriving the modulator; this was first noticed when the trapezoidal pattern was used to check modulation. Distortion occurs before overmodulation, and the modulator still lacks the power to over-modulate the RF. There is no urgent need to change this, as the signal is strong enough and carries well enough to give good results on campus.

An audio amplifier to drive a studio speaker and an engineer's speaker was in demand. Remembering that there was and unused 5 volt winding on the power transformer in the preamp, and that it was rated at 20 ma. more than were being used in the high voltage winding, the type 71-A was chosen (since there were several on hand). This is a four prong filament type tube. The filament, AC heated should be centered about ground by means of resistors, both going to ground. If it is to be filament biased, it will be necessary to have two bi-pass condensers, or to use two small resistors across the filament and the bias resistor to ground from their center. The tube was installed first without the centering arrangement, the bias resistor being taken from one side of the filament, to see how bad the hum was. It turned out to be not bad at all and the circuit hasn't been changed since. If it were to be changed, the value of the two centering resistors should be such that they do not take too much current from the filament supply, and yet they should be only about 1/10 of the value of the bias

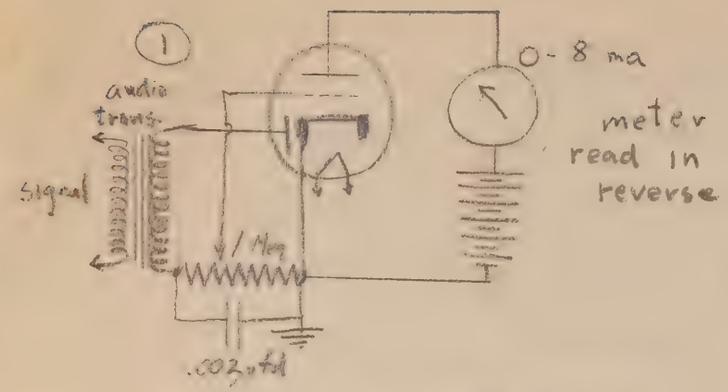
resistor or less. The bias should be 40 volts, I_p = 20ma. The resistance should be 2000 ohms therefore. The five volt winding is rated at 2 amperes and the 71-A draws .25 amps. The resistors may be anything from 2½ ohms at 1 watt up to 200 ohms, 1/4 watt. A suitable value would be 20 ohms. The plate of the tube goes thru the primary of an output transformer mounted in the studio and to B plus. A switch was later added on the #1 mike input to short out the output transformer and cut the speaker. After the engineers booth received the sound-proof double-pane door, a speaker was added in series with the studio speaker and mounted on the wall in the booth. The latter speaker is a magnetic with excellent quality. A switch is connected across it to cut it out too. A slight change in volume is noted when one of the speakers is shorted, but no distortion is produced.

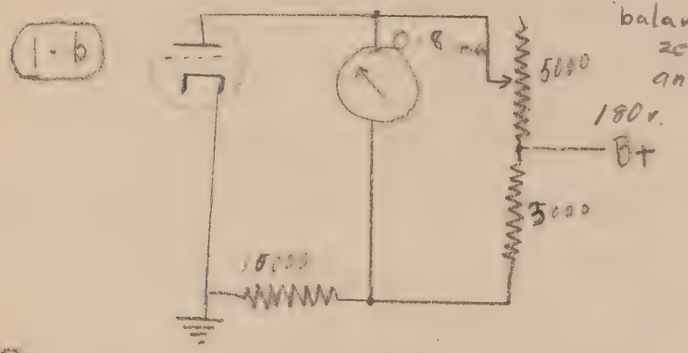
A volume level indicator is a"must"for all stations. The fact that WHAV has not got one is due to the problem involved in getting a meter. Several circuits have been tried and are presented in Figure 18 . An auxilliary power supply was put together from spare parts for just such purposes as these and came in very handy. Circuit #1 makes use of the diode-triode type tube. A 55 was used in the particular# apparatus. A condenser resistor combination might be substituted for the transformer to feed the signal; care must be taken not to make the condenser short out the signal fed to the modulator. Due to the

WHAV

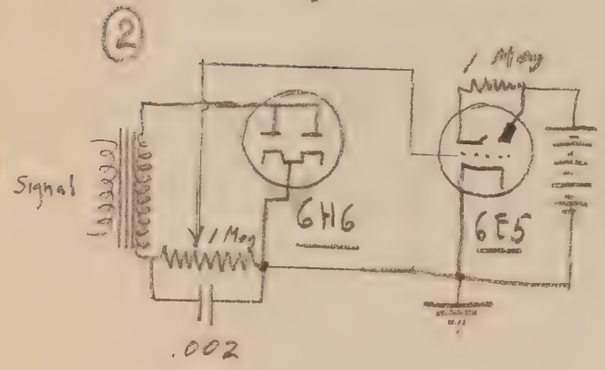
VOLUME INDICATORS AND MODULATION INDICATORS

Fig. 18



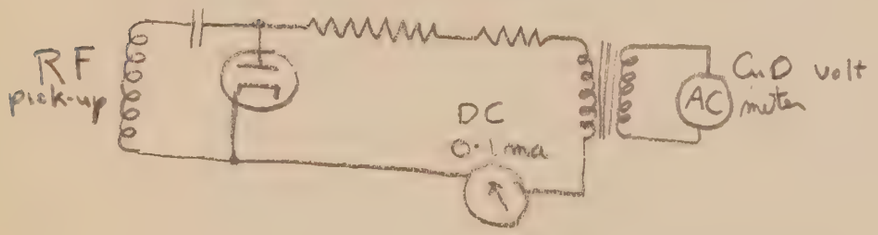


bridge circuit to balance meter at zero signal and read forward

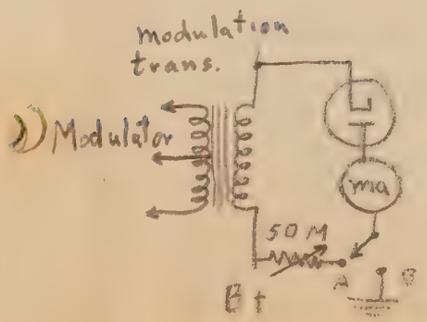


tuning eye for volume indicator - eye closes on maximum signal

3 Modulation Indicator. Will read %



4 Modulation % and Over modulation Indicator



A - Reads % modulation

B - Any reading is over modulation

Note. The tuning eye circuit was built experimentally. Applying the signal voltage directly to the grid causes the shadow angle to flicker open and shut. When at 0 voltage the angle is 90°. Consequently a signal + will close it and a negative signal closes it closed.

The use of a rectifier allows a time constant of .1 to 1 second if desired, which will allow easier reading of the meter

separation of signals on the output of the preamp to go to the Bryn Mawr line and the Haverford Modulator, the VI meter should take its signal from the output of the pre-amp. Then any change in the setting of the modulator will not affect the strength of the signal fed to Bryn Mawr.

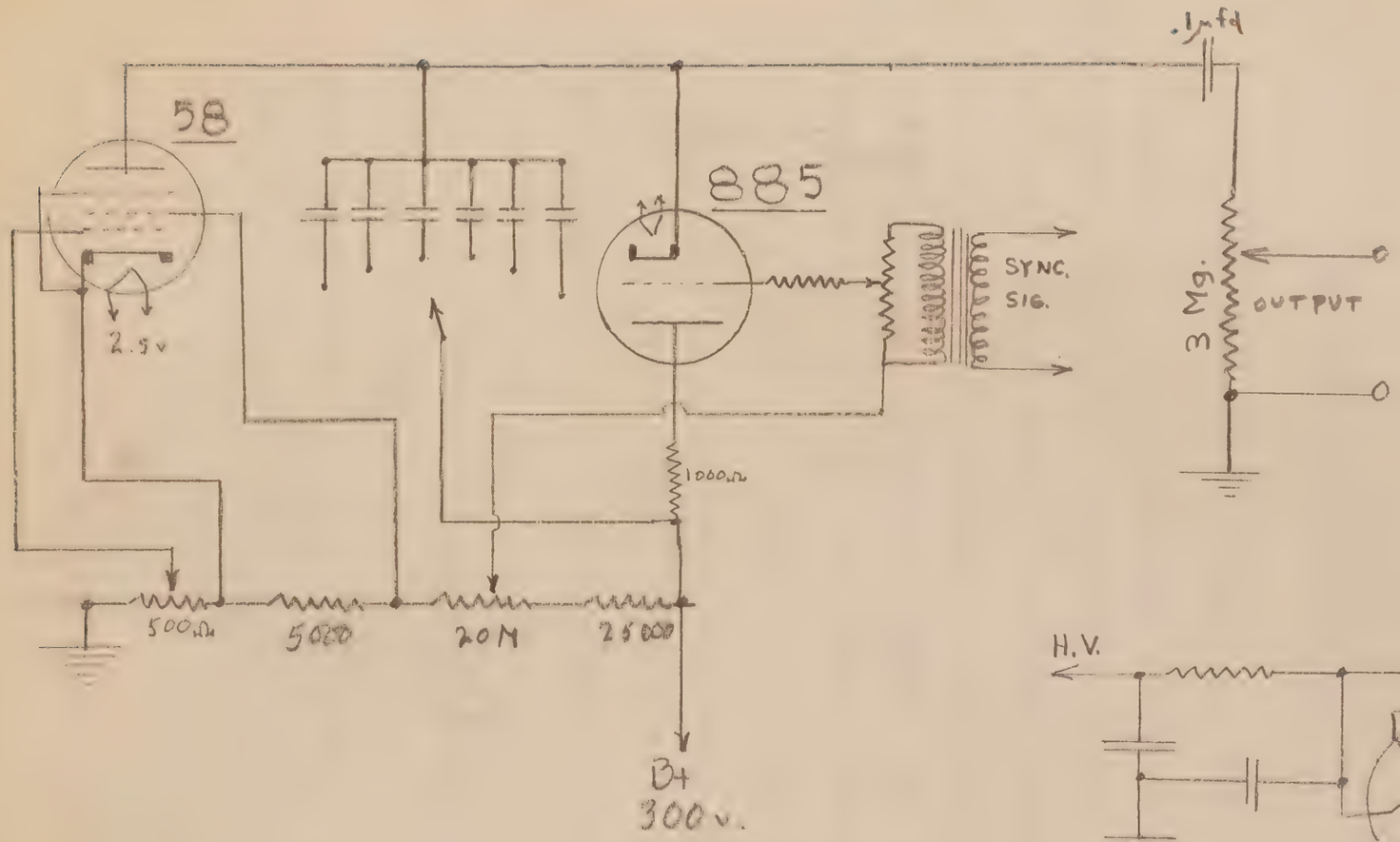
The meter read backwards in the first circuit. There are two ways to get around this. One is to "fix" the meter so it reats at the right end of the scale and the normal currant brings it to the left end. The other, better if one has a good meter, is to put it in a bridge circuit as shown in figure 1-b. The values of resistors may be calculated when the plate current of the tube at zero grid voltage is known. This method wastes considerable plate current. (about 4 times the meter full deflection current)

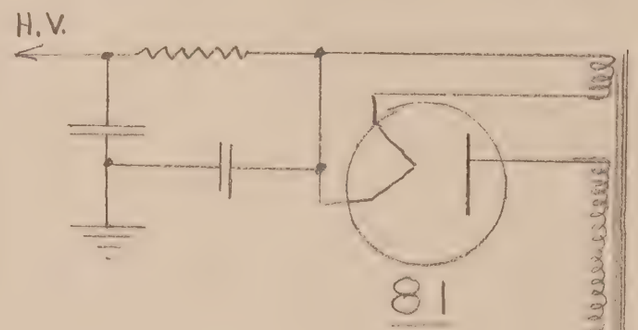
A tuning eye may be made to close on the maximum permissable signal as shown in 2. Adjusting the value of the resistor between plate and target, shown as 1 meg, will control the zero signal shadow angle. The supply voltage will change the cutoff or 0° shadow angle. (max. signal). The best type for this application would be the 6E5. This may be used without a rectifier see note opp.

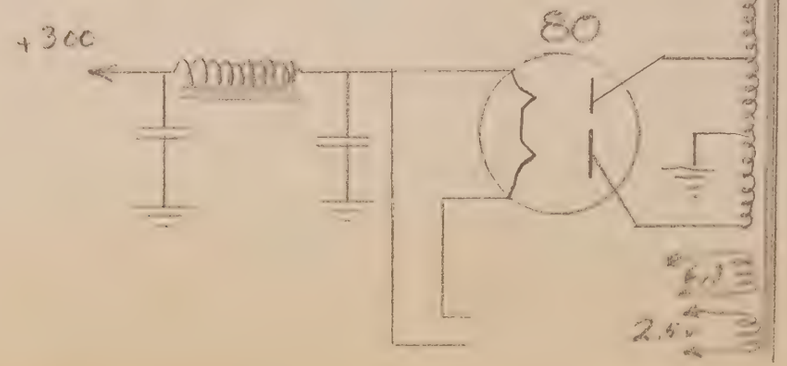
Figs 3 and 4 show plans for modulation indicators. The first may be calibrated to read directly in % modulation, regardless of the signal strength. The meters are set to read equal levels when modulation as determined by trapezoidal methods is 100%. Figure 4 is quite satisfactory if a tube can be obtained that will withstand an 800 volt plate to cathode voltage. It should have a low voltage drop across it and need not carry more than 5 ma. If it is a filament

type, the filament should be battery heated, or a transformer winding with low capacity used. High capacity would shunt the audio notes. If it is cathode type, it must take a heater cathode voltage of 800 volts. In position A it would read proportional to the % modulation, since it just rectifies the audio signal. It would have to be calibrated for 100% again with a CRO. In position B it would read overmodulation since, if the class C voltage is driven below zero, current would flow in the meter. This could be used to calibrate it in position A, but might lead to trouble due to the voltage drop in the rectifier.

A cathode ray oscilloscope that had lain unused in the Physics lab for several years was taken to the studios. Mr. Thomas worked on it until it was satisfactory for use in RF trapezoidal measurements. The sweep circuit does not work at the present, but has been redesigned for use with power supplies instead of the batteries that it formerly required. A type 34 was used as the constant current generator to charge the condensers. This has been changed to a 58 which is a super-control pentode with a cathode. Bias will be supplied by a cathode resistor. Whoever last worked on the CRO placed the condensers in the cathode lead- this should not work, since the screen cannot draw a steady current, and have the characteristics of a constant current generator. The condensers will be placed in the plate lead, as shown in the figure.[19] To eliminate the bias cell for the 885 grid, it will be returned to the bleeder resistor. Thus when the plate stays at B plus, and







WHAV

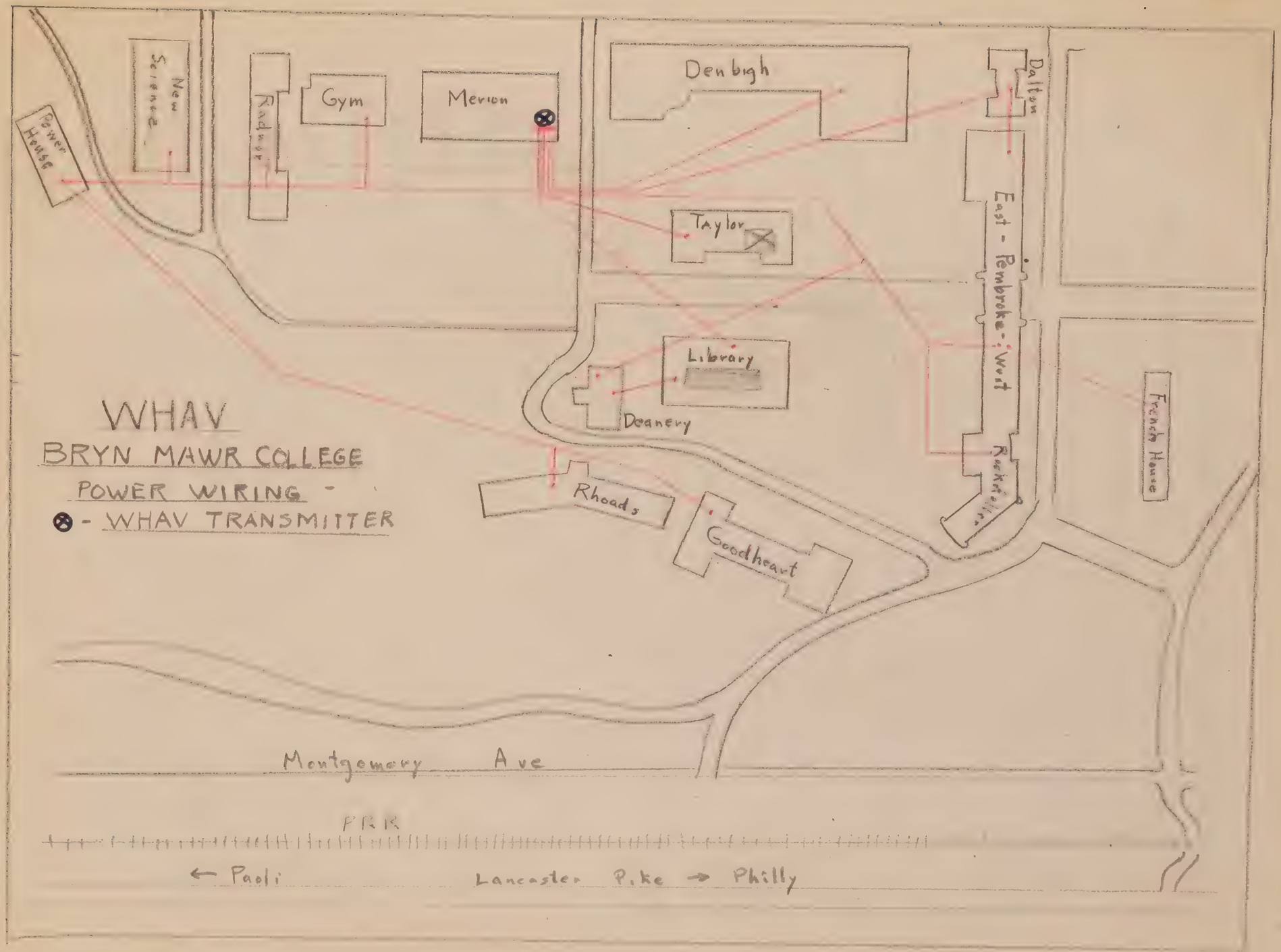
REDESIGNED
SWEEP CIRCUIT
CATHODE RAY OSCILLOSCOPE

the condenser charges, the plate of the 58 and cathode of 884 will eventually go negative with respect to the grid of the 884, and the latter will discharge. The 884 and the cathode ray tube have 25 volt filaments, and the 58 will not overload the transformer.

The Bryn Mawr Transmitter

In November, 1942, a telephone line was rented from the Haverford Union to Goodhart Hall at Bryn Mawr. As a temporary stopgap, the programs were fed from the line, thru a mike transformer to the phono input on a radio in the common room in Goodhart. Reception was good, but few students came to listen. Design of a transmitter had already been considered, and was now hurried.

In this case, the choice of location was fundamental to the construction of the transmitter, since, as yet, most of Bryn Mawr is on DC, but parts have AC available. Consultation with the superintendant of grounds showed that the power was distributedfrom Merion Hall, except that for Rhoads. Thus Merion, rather than Goodhart would be the best place for WHAV's new transmitter. Only DC is available there: that leaves two choices 1) generating AC with an inverter or a vibrator, and rectifying it, ~~the~~ stepping it up to the desired high voltage 2) using the 220 volts DC for the power supply and filtering out the ripple. The latter was chosen because of the equipment saved. The problem of

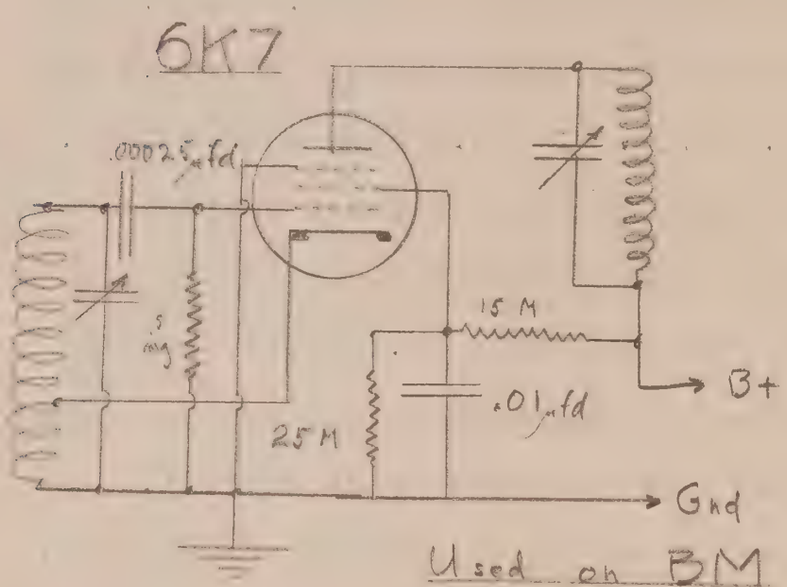

WHAV
BRYN MAWR COLLEGE
POWER WIRING -
⊗ - WHAV TRANSMITTER
Power House
New Science
Radnor
Gym
Merion
Denbigh
Dalton
East - Pembroke - West
Taylor
Library
Deanery
Rhoads
Goodhart
Rockefeller
French House
Montgomery Ave
PRR
← Paoli
Lancaster Pike → Philly

filament current took longer to dope out. The tubes that were to be used were ones taking respectively .3, .7, .9, .9 ,.9, .9, and eventually two more at 1 amp each. All but the last two are 6.3 volt filaments. Putting them in parallel and using a dropping lamp would be very difficult, taking 4.6 amps Finally it was decided to put them in series and shunt the smaller ones with resistors to use the rest of the .9 amps. The resistances for the first two tubes have to carry .6 and .2 amps respectively. 6.3/.6 = 10.5 ohms and/.2 = 31.5 ohms These were wound from some old wire wound resistors in the stock pile and measured on the Wheatstone bridge box in the Physics lab. To drop the 110 dc to 37.8 volts, regular lamps were put in series and the current and voltage measured. 140 watts worth of lamps gives the correct current.

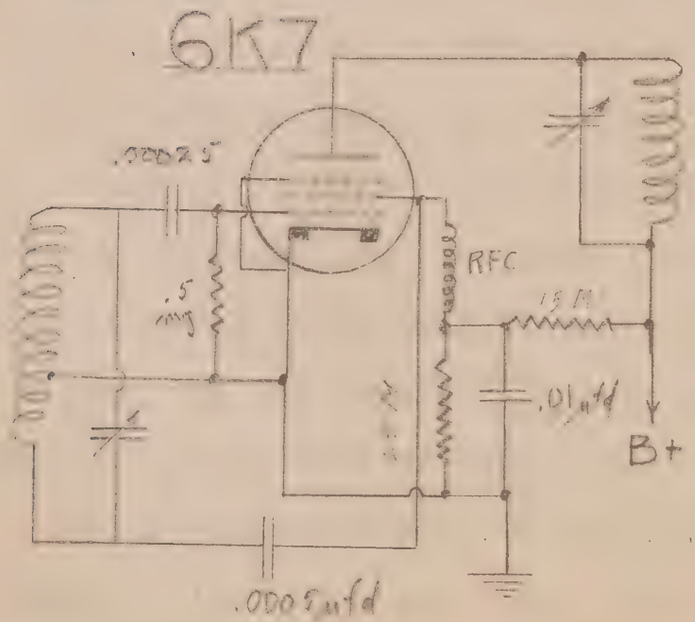
Since the chances of getting a crystal seemed slim, other methods of RF generation were considered. The best seemed to be the electron coupled oscillator. A 6K7 was used and the oscillator section built up for testing. To eliminate any trouble from magnetic coupling back to the oscillator grid tank, it was decided to tune it to the sub-harmonic of the desired frequency. 580 Kc had proved troublesome at Haverford because of a powerful Cuban station which gave a beat note with the WHAV signal and provided some audio interference also. Since there is nothing at all between WIP at 610 Kc and WEAF, N.Y. at 660, the frequency of 640 Kc. was chosen. The oscillator tank was then built to tune at 320 Kc. The tank circuit in its plate was tuned to 640 Kc.

ELECTRON COUPLED OSCILLATOR

TWO METHODS OF CONNECTING



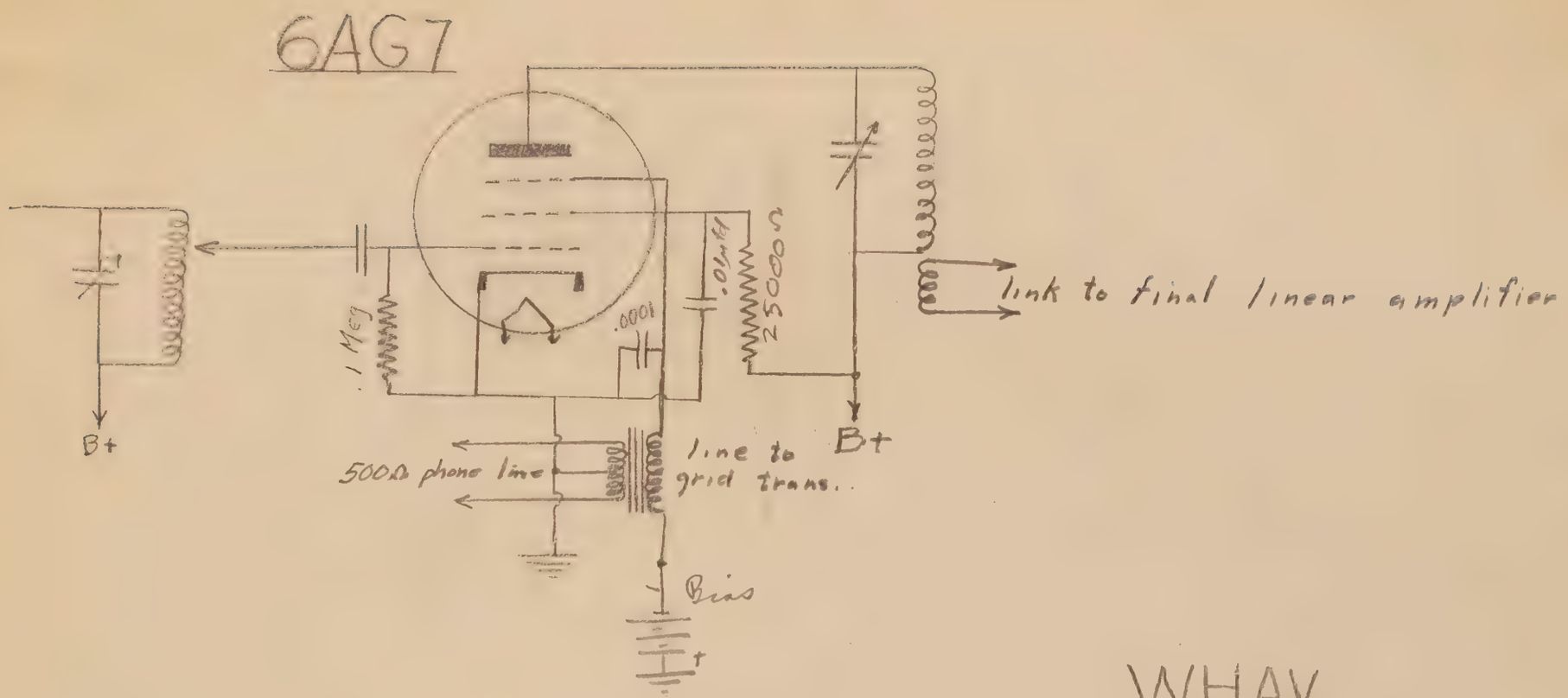
Used on BM Transmitter



For stability the screen potential was obtained with a potentiometer rather than a series resistor. In an electron coupled oscillator, the screen grid acts as the oscillator plate; therefore it may be connected one of two ways. The cathode may be grounded, and connected to the tap on the coil, and the screen, fed thru an RF choke, returned to the bottom of the grid tank, thru a condenser or the screen may be bi-passed to ground and the cathode returned to the tap on the coil. The latter was chosen for several reasons. It provides better shielding between the plate and the other elements. It eliminates the need for an RF choke, which always brings in the danger of parasitic oscillations. The suppressor grid must be grounded, not connected to the cathode, for better shielding.

The design of the remainder of the transmitter rested upon several considerations. The method of modulation was in question, especially since no modulation transformer was available. After considering the possibilities of using a 6F6 driver suppressor modulated, and a linear push-pull 6L6 power output, or attempting to grid modulate, or even to use choke modulation, the engineers gave up and trusted to their lucky star to provide them with a modulation transformer. Fig. 21 is the suppressor modulated circuit that was designed.

The output was chosen to give power needed to cover Bryn Mawr, especially since only 200 volts at the most would be left for plate supply after filtering. To find out how well the RF would carry at Bryn Mawr, the entire transmitter



WHAV

POSSIBLE BUFFER AMPLIFIER FOR SUPPRESSOR MODULATION

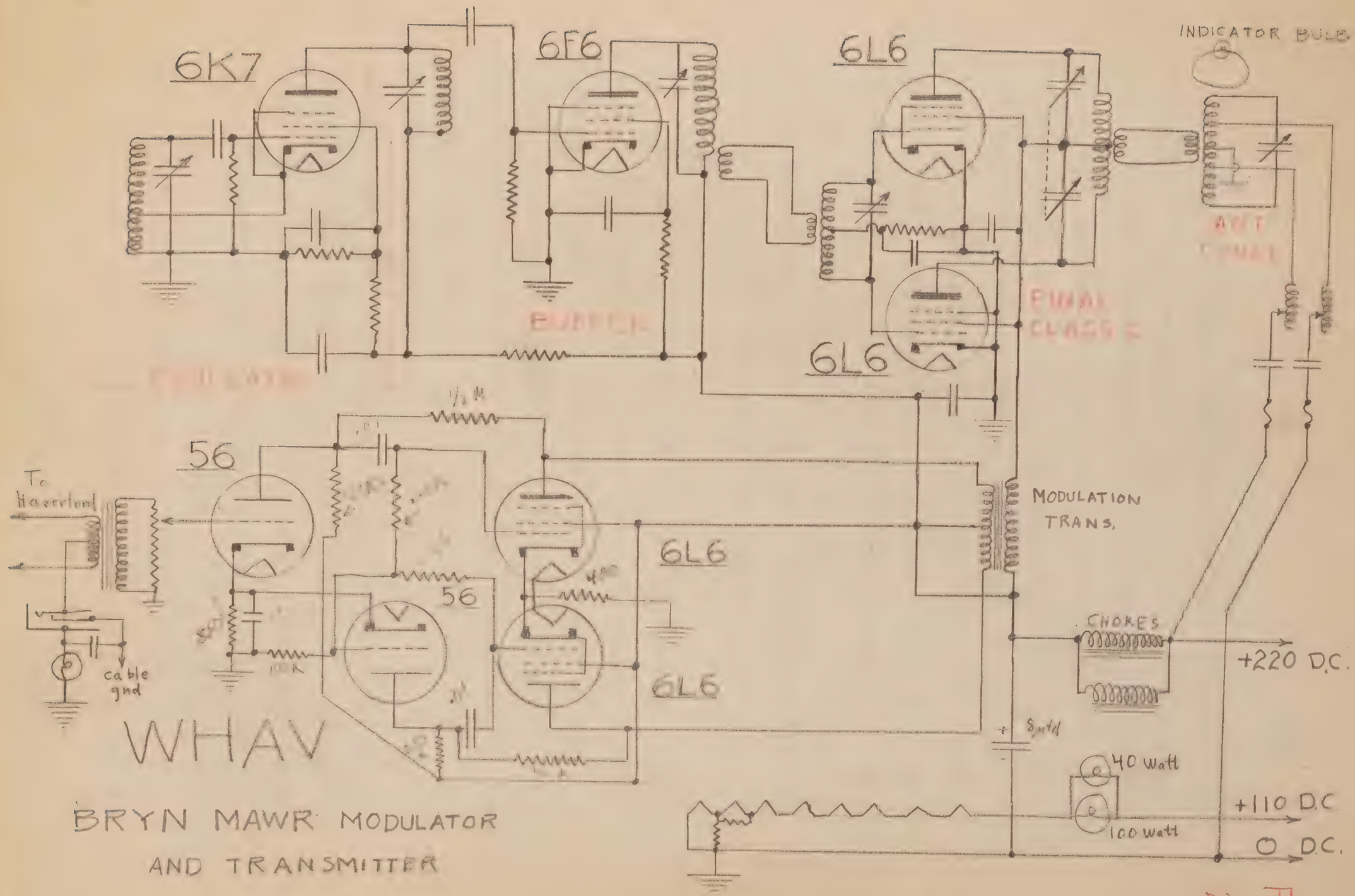
Possible tubes - power amplifier pentodes with external suppressor (vidio power amplifiers)

for design considerations see ARRL Handbook 1942

11-9-21

of WHAV was transported to Bryn Mawr one week-end and tried out. From Goodhart, where AC was available, it could only be heard in Rhoads Hall. From Dalton Hall, the physics lab. the signal could be heard in Merion, Denbigh, Pembroke East, and faintly in Pem. West and Rockefeller. Obviously more power would be needed. In general, more power is required to cover the same territory on DC power mains; the reason is that equipment for DC operation does not count on inductance to keep the current down, therefore, more of the equipment is a short-circuit to RF. With this in mind, the final class C amplifier was designed with pushpull 6L6s of which there were three extra in the stock pile. (A large amount of radio equipment was donated by a student who had received it from a friend who worked on the Atlantic Cable.) A power buffer amplifier was needed to drive the final, and a 6F6 was chosen.

The method of coupling to the pushpull grids was debated (mentally) for some time. It was decided to tune the plate of the 6F6 and link couple to a tuned grid tank in the final. A two gang condenser was found which would serve in the plate circuit of the final and not break down with the RF across it. The center tap of the coil was connected to the common (frame) of the two gang condenser, and bipassed to ground, (this lowered the peak voltage across the condenser by 200 volts). Profiting greatly by the experience with the Haverford transmitter, all coils were wound with heavy enough wire (#22 enameled) to give a decent Q. The antenna tuner, links, and series resonant feeders were all shellaced to prevent trouble with moisture, since the transmitter was to be in the basement.



Destroyed (in fire) 1944

Fig. 22

The whole apparatus was mounted on breadboard in short order. The modulator, which was at first a single ended 6L6 driven directly from the line, was mounted on the board that had been used for the line to grid transformer in Goodheart. Several old 30 hy. chokes with 800 ohms DC resistance were put in parallel (to cut down the voltage drop), and a condenser put on the output. No condenser was used on the input because it would short out the RF. Later it was learned that electrolytic condensers have high resistance to RF. The magnitude of this is not known to the author, but it might prove possible to put an electrolytic condenser on the input. The transmitter was finished this far in mid February.

The author and Robert Day, after a conference with Miss McBride, presented a letter to be read at the next meeting of the students association. It asked for help in the cost of the transmitter, $11.00, and the phone line, $5.75 a month, for the rest of the year. These were granted, and permission given to install the transmitter. The letter was misunderstood at a meeting of the radio club at Bryn Mawr, and the day before Spring vacation it was voted that the transmitter be turned down. (They thought they were to have a studio at Bryn Mawr) After explaining the mistake to Alice Minot, the president of the club, the transmitter was installed during spring vacation. Opening was scheduled for Monday night following.

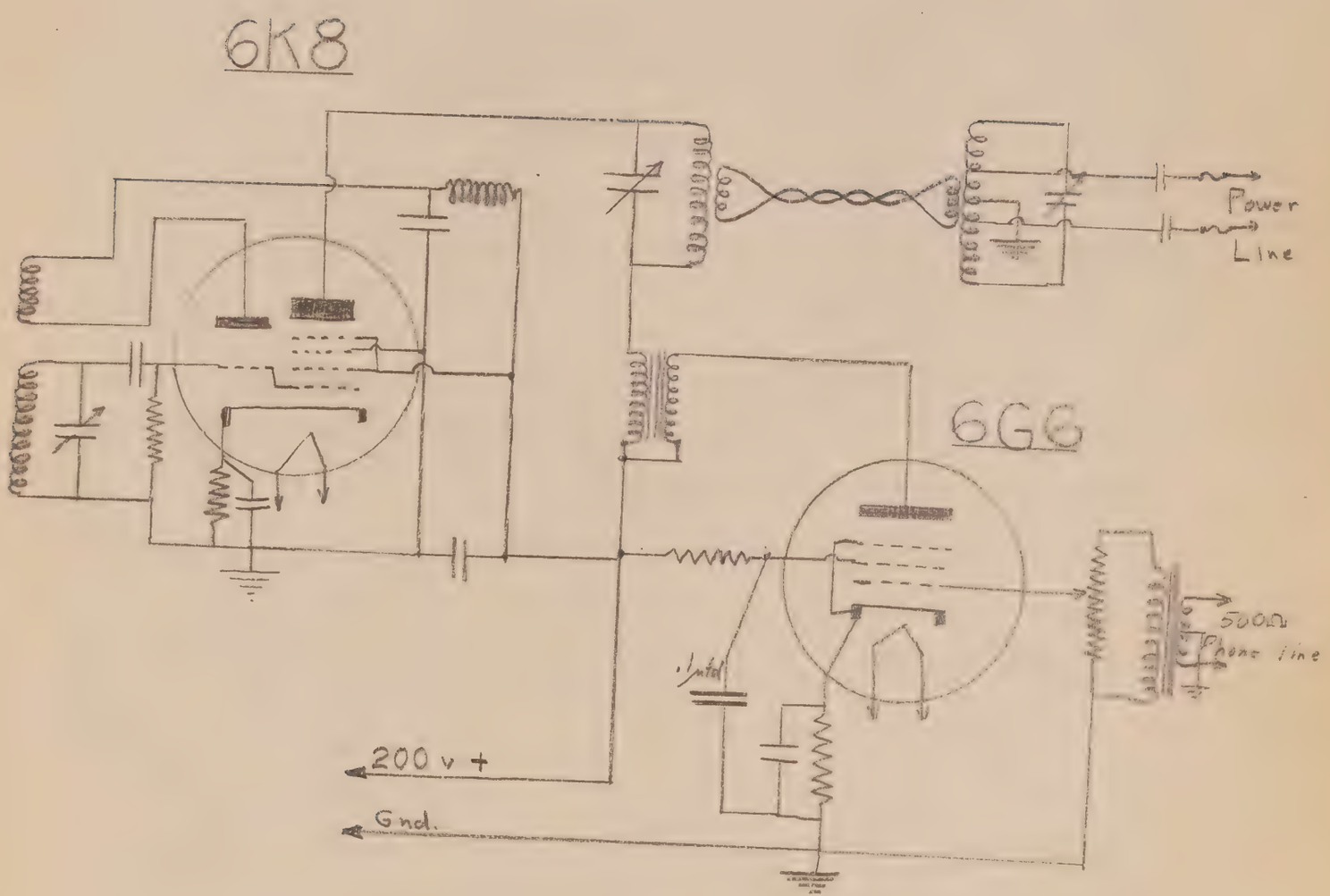
In usual WHAV last minute haste, no modulation transformer

had been secured. Some very clever ideas had been developed for substitutes. Among them were the following:1) use of an old delta to wye power transformer capable of handling a kilowatt. Mr. Chapen, the engineer said he had one that was not in use, if we could bring a derrick. This would have a turn ratio of 1:1, which is approximately correct. The plate of a single 6L6 should be 3500 ohms impedance, that of the final class C amplifier was calculated as 3000 ohms. 2) Use of a Variac - the turn ratio could be varied here, but the number of turns is quite small and it would not be a good transformer. 3) an auto transformer with more turns than a variac, (questionable) therefore better match and probably better frequency response, could have been bought in Philadelphia. 4) choke modulation was considered but not for long because 5) In a fit of optimism a letter was sent to Archer and Evinger in Terre Haute, Ind. requesting a modulation transformer and giving the desired specifications. WHAV had $5.67 credit there and told them to send the rest collect. The transformer came on Tuesday. It went into operation that evening. (Mr. Benham had kindly lent his for Monday night but needed it back on Tuesday - WHAV's lucky star!)

It was not expected that Rhoads Hall would recieve the signal. There is lots of static caused by all the DC equipment at Bryn Mawr, and reception is not good in Rhoads. The small transmitter shown in figure 23 has been designed to cover Rhoads, operating from its basement. It would be fed from the phone line directly (a branch being run to the

Fig. 23

WHAV
TYPICAL
LOW-POWER
TRANSMITTER



location) The identical apparatus, with the exception of the modulator,has been constructed and tried in Founders. Without being connected to the power wires, it covers the entire building adequately. It was picked up in fifth entry Lloyd, but very weakly. Of course, the frequency would have to be different from the main transmitter unless it were syncronized exactly with it by means of an RF amplifier. The easiest solution would be to operate on 630 Kc. This band is just as clear as 640, but is closer to WIP, 610. The 6K8 would have to be purchased. The modulation transformer could be an old audio transformer, since the modulator draws only 15 ma. plate current and the pentode of the RF draws only 8 ma. The matching should be 10000 ohms to 25000 ohms. An interstage transformer with a 1.5:1 ratio would suit this. In the trial circuit, an audio transformer was used, and the modulator was a 25L6 Beam Power output. The screen grids were not modulated, but it worked, somehow. In this case the current would be 2.5 ma. and the matching would be to 80000 ohms. A 3:1 audio would do the trick.

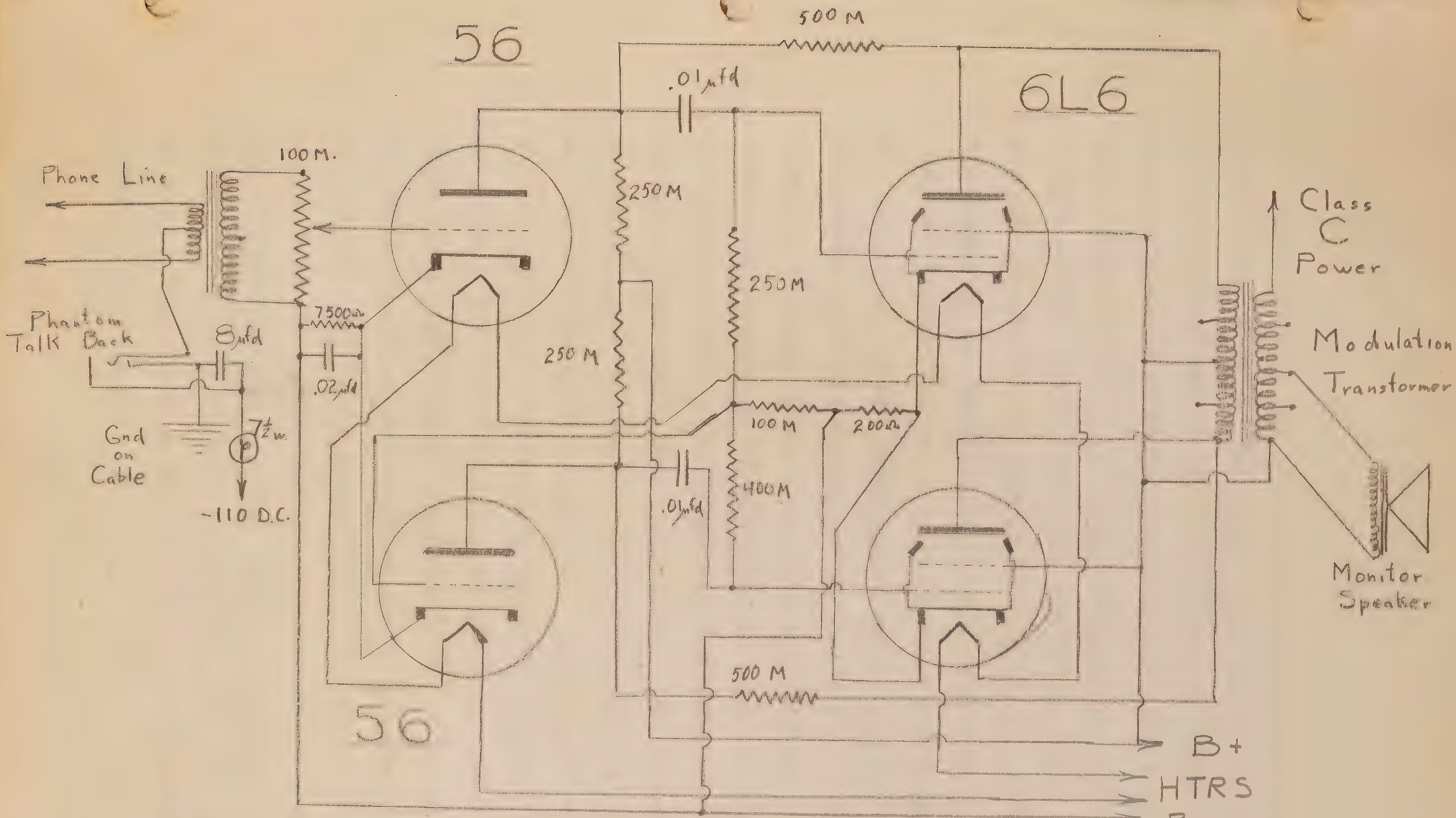
In less than a week it was decided that the modulator did not have enough driving voltage. A 56 was added to it, chosen because of the heater current of 1 amp, (.9 would be enough) A test such as described for the Haverford Modulator showed that only 4 watts could be drawn from the 6L6G undistorted. The next step was adding the other 6L6 to make it push pull. The driving voltage was to be obtained from an interstage transformer. The whole thing was constructed

and the frequency response measured. It began falling off at 1500 cycles. This was due in part to the interstage transformer and partly to the line to grid transformer. With constant input on the grid of the 56, the output voltage was down 50% at 3500 cycles. The next step was phase inversion, which was accomplished with another 56. The circuit was adapted from the WHAV modulator. The gain of the 56 is not as great as that of the 6SC7 used in the WHAV modulator, but due to the balanced phase inversion, the amplification is relatively independant of the tube amplification. The feedback factor β is .2 and the voltage amplification of the 56 is 10 at the plate voltage and with the circuit constants used. Substituting in the formula; gain = $\frac{10}{1-(-.2\times10)}$ = 3.3 Since it takes only 1/6 of the voltage from the input to the first 6L6, the voltages fed to the two grids have a ratio of 6/3.3 Keeping the feedback factor constant, changing only the grid resistor of the first 6L6 called x and assuming 1 v. on grid of first 6L6

$$\frac{.1}{.1+x} \times 3.3 = 1. \qquad x = .25 \text{ meg.}$$

All that need be done is to change the grid resistor on the first 6L6 to .25 meg. The resistor on the second grid is .4 mg.

The frequency response of the phase inverter and push pull output is flat from 30 to 15000 cycles, not including the output transformer, which drops off slowly at the lower frequencies. See fig 16.



WHAV

NEW BRYN MAWR

MODULATOR

CONSTRUCTED MAY 1, 1943

The modulator was installed at Bryn Mawr on Saturday, May 1. With a signal, provided by the RME, on the phone line the transmitter was tested. The monitor speaker at Bryn Mawr is connected across a part of the secondary of the modulation transformer, and is a high impedance magnetic speaker. The signal sounded fairly good, and, not having heard that particular speaker with a good amplifier, the slight distortion was blamed on the speaker. It didn't sound too good in the earphone monitor either, so without any instruments, a testing job was begun. After shorting out grids to ground, parts of the modulation transformer, and the heaters on some of the tubes to make them inoperative, the two 56s were traded. Just after they were plugged in, it sounded wonderfully. That confirmed suspicions but confounded the engineer. It was noticed, on repeating, that a wire wound cathode resistor of the two 6L6s got red hot when one of the 56s was extracted, but not when the other was removed. Since the filaments are all in series, disconnecting one of the tubes would put 110 between all the other tubes on the + side of it at 110 volts above ground and all those below it at ground. One of the 56 filaments was connected on the plus end of the 6L6s and the other 56 on the ground lead. The only explanation seemed to be that after heating up a few seconds, one of the 6L6 cathodes was shorting to a part of its filament. This was confirmed by exchanging 6L6s with one of those in the class C amplifier. The faulty tube was donated to the "stump the ESMWT with these" pile of tubes.

Some thought has been given to the possibility of a remote control for turning on and off the Bryn Mawr transmitter. Relays operating on 50 ma. could be used, but no current may be passing thru the line while in operation since it would saturate the core of the transformer. A single relay that had two windings, both polarized, could be used to lock on and unlock a master relay. In this case current would be reversed to turn off the transmitter. The scheme shown in fig. 15 is somewhat more practical, and the condensers would help to improve the high frequency response. They would cause a falling off much too rapidly in the low frequency ranges however. The alternative method is now possible on both ends of the line. The output transformer at Haverford has two separate windings on the secondary, as does the input transformer at Brym Mawr. Care must be taken that the center taps are always at ground potential or else connected together. At Haverford a condenser between the center taps of the two windings would be satisfactory. At Bryn Mawr, a condenser should shunt each relay coil for the engineers ~~monitor~~ talk back to work properly. The relay could be adjusted to close or open on the difference in current taken by the phantom circuit thru the Haverford instrument and with the Haverford phone shorted to ground. In this way, the BM ~~monitor~~ talk back phone would always be connected, but drawing no current. The Haverford engineer could draw button current without closing the relay, but shorting one side to ground would turn on or off the transmitter. This would be somewhat hazardous due to the drift of the Bryn Mawr supply system with respect to ground.

In connection with relays, it might be mentioned that there are several power relays lying around he Haverford physics lab. that came from the world's fair. They might prove useful. For the present, one of the Bryn Mawr engineers will continue to turn it on and off.

Studio Improvement

It would be useless to mantion all the things that have been done to improve the studio since November. Several are of interest from an engineer's standpoint,however, and will bear mentioning.

A signal light system was installed with a switch to turn on a red light in the studio (meaning silence) and a foot switch to turn on a white light (the cue to speak). The foot switch was made self locking and is released by kicking the catch. Two synchronous electric clocks are now in use, one in the engineer's booth, the other in the studio. They keep within 2 or 3 seconds of the Bureau of Standards time signal which may be found on the RME at 5 megacycles. The time signal is given thus: the 440 cycle note goes off every five minutes on the five minute interval, and comes back on one minute later. Thus it is off from 4:10 to 4:11. These clocks should be set once a week.

At the beginning the studio had a queer appearance about it. The walls were covered with blankets to be sound-killing. As winter approached, the owner's need for the blankets grew, and so

did the need for decent sound proofing. Celotex was investigated. The material used for sound absorbing, which is made with a flat absorbtion coefficient of 50% (of that of an open window) for all frequencies, costs prohibitively for WHAV. Other material was investigated. Several martyrs volunteered to drill holes in regular cheap celotex to make it absorbant. Fortunately the idea of using rug matting was suggested by Dr. T.O.Jones before anything drastic was done. Sears and Roebuck supplied the need with two 9 by 12 ft. rugs at about $1.90 apiece, plus delivery. The only difficulty is that it comes off on the clothes.

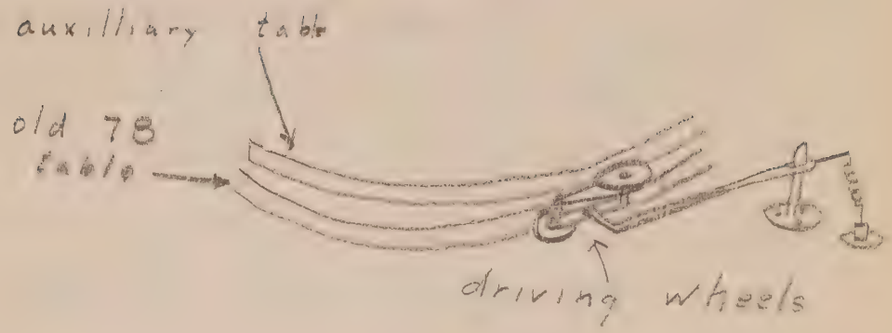
The sound proof door to the engineer's booth was constructed from a large piece of discarded celotex in the physics lab. Unfortunately, Mr. Benham had had designs on it too. Double panes of glass were supplied by Mr. Johnston.

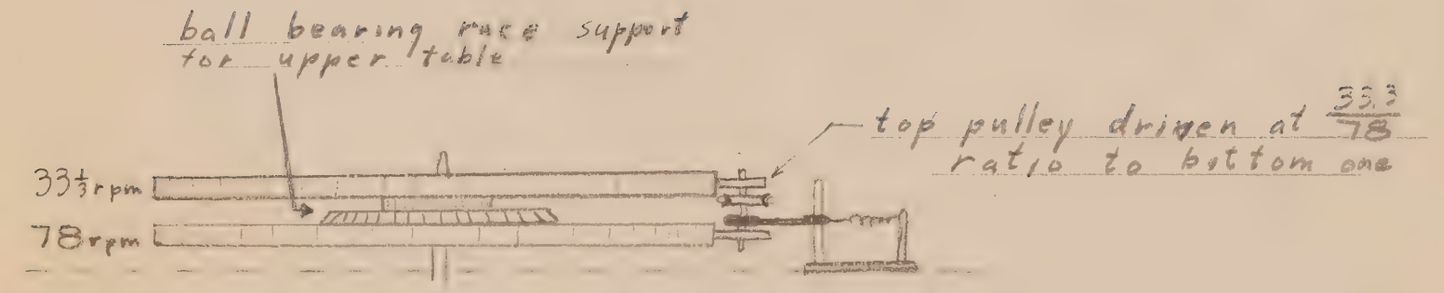
The following microphones have been used: 1) the Astatic T3 belonging to the Physics lab. has been in the studio since September. 2) The RCA velocity mike belonging to the ENglish and Music dept's recorder. This fine mike has now been traded for 3) an Electro Voice Dynamic, a low output velocity mike. The input of one mike channel on the preamp was changed from a 6F5 to a 6J7, pentode connected, to increase the gain for this mike. 4) Mr. Benham's crystal mike has been borrowed. There should be a carbon mike in the engineer's booth and an amplifier that will feed the 71-A or the preamp output. This could be used for talk balk to the studio, to the next room and for one man programs announced by the engineer.

WHAV

Fig 25

PLANS FOR 33⅓ R.P.M. TURNTABLE - by Alan S. FitzGerald





Most transcriptions are recorded on 33 1/3 rpm disks. WHAV has no method for playing such records, should they ever be obtained. For future reference, let it be recorded that 1) the turntable in the music room is able to play at 33 1/3 and that 2) Mr. Alan S. FitzGerald has worked out a plan for a 33 1/3 auxiliary table to be set on top of another table, the latter running at 78. The upper table is mounted on a ball bearing platform centered on the lower and driven at the rim by a rubber wheel which is driven at the proper reduction by another rubber wheel resting on the edge of the lower table. This is sketched roughly in figure 25.

The Uses of Carrier Current

The first extensive use of carrier current was made by the Bell Telephone Company. The search for methods of getting more than one communication channel from one pair of wires had interested men as far back as Bell himself. When the vacuum tube became usable about 1912, telephone engineers were quick to apply it to their work. First to the amplifiers, then to carrier current. From the beginning of its use, telephone carrier current has been single side-band. The details of this may be found in Terman, Radio Engineering pp 415-17, and will not be described here. At present, it seems that all telephone messages are soon to be carrier current. Cables are now designed to carry the high frequencies. Coaxial conductors are being laid which will carry

frequencies up to 1 megacycle. Hollow wave guides, in experimental stages only, will work only above frequencies of about 1000 megacycles. These may prove to be the telephone lines of the future.

Carrier current found many uses where there were wires used for other purposes already. The power companies do everything from turning on street lights to talking to service men out on the line by use of carrier current. Factories and stores, offices and homes all use inter-communication systems without stringing any wires. A large chain of "juke boxes" is operated from a central office by carrier current. Since they have been forced off the air during the war, amateurs have started using carrier currents down below the broadcast band. As they have done to so many fields, the amateurs are opening up this band of frequencies from 50 - 550 Kc.

It is beyond the scope of this paper to more than mention the extent to which carrier current has been applied to college broadcasting. About 40 colleges have carrier current stations. Most of them either have contracts or keep in occasional contact with the IBS, the Intercollegiate Broadcasting ######## System. The technical department of the IBS is helpful in sending out hints on how to get around difficulties and reports of how other colleges have solved certain problems. They also send out monthly lists of all articles issued in recent periodicals of interest to college broadcasting engineers.

INVENTORY - WHAV

Electrical Equipment

No.	Item
1	Transmitter at Haverford
1	Transmitter at Bryn Mawr
1	Transmitter power supply - Hav.
1	general power supply - BM
2	auxilliary power suplies
1	modulator - Hav
1	modulator - BM
1	preamplifier
2	phono turntables, 1 temp. (Clark)
2	microphones, temp.
1	RME 69 radio
1	Majestic TRF radio
1	Cathode Ray Oscilloscope, temp (Physics Lab.)
2	synchronous clocks
1	PM dynamic speaker
3	good magnetic speakers
1	good dynamic speaker
1	volume indicator
2	carbon microphones
3	telephone headsets
1	French phone

Total no. of tubes including all in use (in RME included)

3	01A		
1	6B7	1	42
2	6C5	2	45
1	6C5G	1	55
1	6C6	2	56
5	6D6	1	57
2	6F5	2	58
2	6F6	1	71A
1	6H6		
1	6J5		
2	6J7	Rectifiers	
1	6K7		
3	6L6	1	5Z3
4	6L6G	1	6X5GT
1	6SC7	7	80
2	6V6GT	1	83
1	12SA7		
1	25A6	Miscellaneous ancient uncatalogued tubes.	
6	27		
1	34		
1	38		

Inventory- cont.

Miscellaneous radio parts:

several interstage transformers
one output transformer
one small choke.
several induction coils
assorted resistors
" consensers
2 variable condensers
" coils
wire of all sorts except push-back
25 feet of 12 conductor cable
sheet copper
supply of terminals, switches, plugs, jacks, etc.
can of screw, one of nails
box of machine screws

Furniture

2 large tables
1 small table
1 desk
10 chairs
1 wicker sofa
5 rugs
1 mike table stand
1 " " " ,temp. (Foreman
1 floor stand, temp. (Dining Room)
2 book cases
3 mike covers
2 engineer's turntable covers
curtains, cloths, lights, sockets, extension cords, hardware

Addenda:

1 Line to grid transf.
1 CL104 Astatic Crystal Pickup

Summary of unsolved problems and suggested work.

To be done as soon as possible:

1) Change phase inverter constants as suggested on page 61 on the Bryn Mawr Modulator -(Has been done)

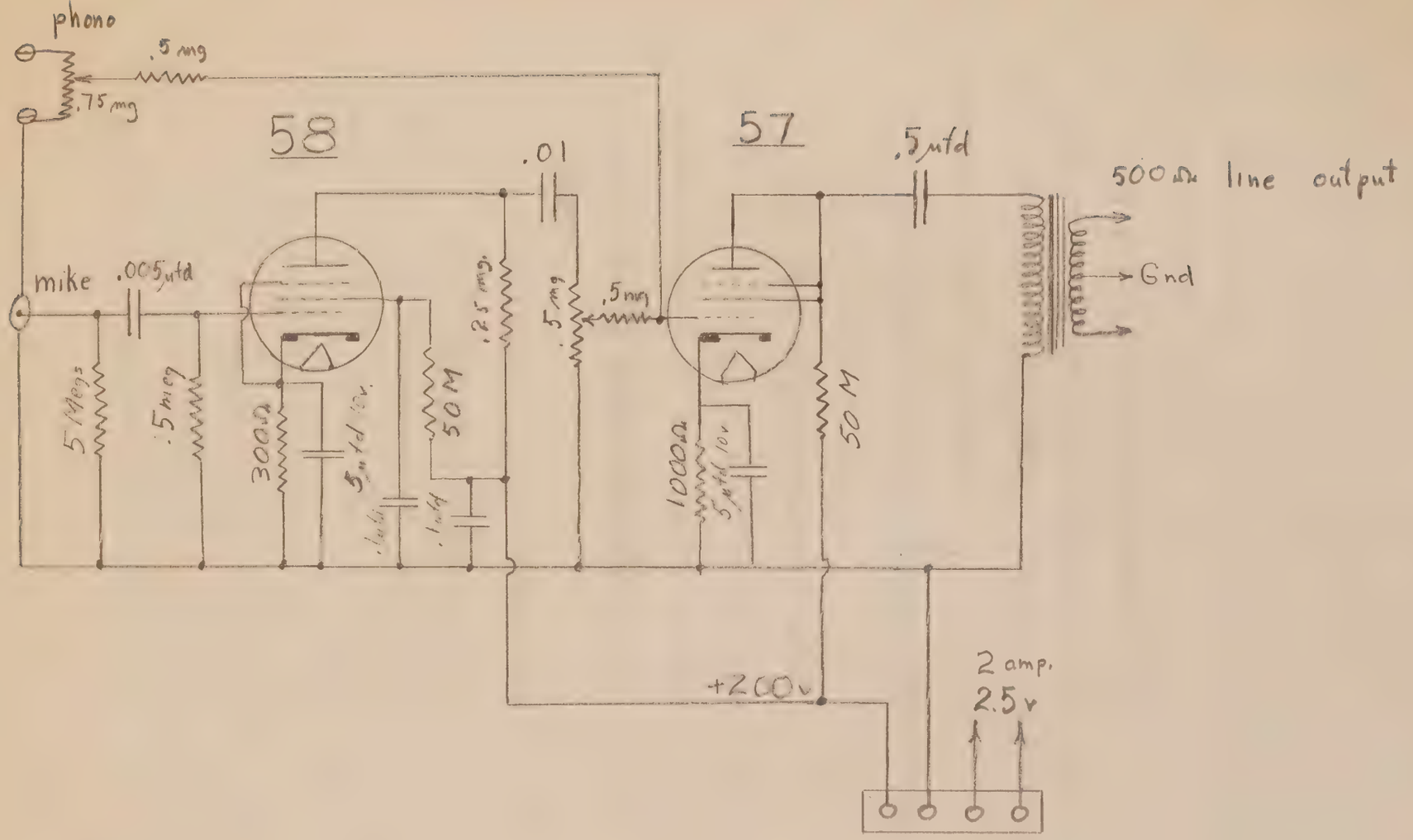
2) Change the secondary connections on the line to grid transformer at Bryn Mawr as suggested on page 44. (Has been done)

3) Change the equalizer on the Bryn Mawr line. Several things should be tried. The point of cutoff can be made 6000 cycles by placing a 2.5 mh choke in each side of the line. This would resonate with the .3 mfd. shunt capacity of the line at 6000 cycles and act as a low pass filter. The attenuation up to 6000 would probably still increase, the the condenser resistor combination (page 41-2) might help. The line may be fed directly from the 500 ohm output of the ~~audio oscillator~~ output transformer, feeding the preamp input with oscillator. A cathode ray oscilloscope ~~may~~ might be borrowed from the Bryn Mawr physics department. See Dr. Patterson.

Suggested changes:

1) Move Barclay feeder away from the attic and carry it around the 2nd floor level of the Union from the middle room over to where the PA line goes into the auditorium window.

2) Build a portable preamplifier, using the auxilliary power supply mounted on a breadboard. If it works satisfactorily, there are almost enough parts for a power supply. The suggested diagram is given in figure 26.



WHAV

PORTABLE PRE-AMPLIFIER

Fig. No 6

3) Remove all the shielding on the leads of the grid of the triode 6J7 in the preamp. This should improved the high frequency response. Watch for cross talk.

4) Erect a 155 foot antenna to the roof in Lloyd hall(p29-30) Has been done

5) Try receiving FM on the transmitter; verify if possible the hypothesis. (pp 15 - 17)

6) Measure frequency response of the:

a) preamplifier after changing mike input to 6J7 and removing all shielding. Apply negative feed back to cathode of triode connected 6J7. (pp39-40)

b) transmitter, plotting modulating voltage vs. % modulation. (pp. 45-47)

c) Bryn Mawr transmitter the same.

7) Try placing an electrolytic condenser across the input of the power supply at Bryn Mawr. Recheck field strength. Better filtering of the plate supply to the 56s might cut some of the racket.

8) Check transmitter plate voltage and current both at Hav. and BM. Calculate the impedance presented to the modulation transformer and reconnect if necessary. $Z = \frac{E_p}{I_p}$

9) Build a small transmitter for Rhoads Hall if reception cannot be made satisfactory. (pp. 59)

10) Install an engineer's mike with a separate amplifier to drive either the 6C5 output transformer or the 71-A grid separately for talk back purposes.

11) Balance the filaments and bi-pass the cathode resistor on the 71A (pp 50-1)

12) put another speaker on the 71A in the second room, contolled from the booth.

13) Fix the CRO borrowed from the physics lab as shown in fig. 19. A vertical amplifier would add greatly to its value, and would be appreciated by the Physics lab. Circuits may be found in Electronics, or in the publications by industries such as the pamphlets of Cornell-Dubliere.

Aims for the future

1) Permanent mounting of all equipment on metal chassis.

2) A studio at Bryn Mawr with all equipment for producing and airing programs. June 1, 1943 — has been done

3) Purchase of an FM receiver. Has been done!

4) Purchase of two good microphones.

5) Extending coverage to Merion, Language House, and Government house.

6) A second studio in the third room on the third floor of the Union, with the possibility of moving the engineer's booth to the middle room with windows to the other rooms. Getting there!

In building, one learns. Those who follow the present engineers will enjoy most and profit greatly from work they are able to do to improve the station. This summary is presented to help as a guide for the energies of those who are seized with the desire to create or improve.